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Kitsutaka

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(54) **IMAGE GENERATING SYSTEM AND PROGRAM**

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(2), (4) Date: **Aug. 27, 2001**

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**
G09G 5/02 (2006.01)

(52) **U.S. Cl.** **345/592**; 345/589; 345/422; 345/629; 345/630

(58) **Field of Classification Search** 345/589, 345/592, 422, 629, 630
See application file for complete search history.

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EP	1 056 050 A1	11/2000
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JP	A 09-091451	4/1997
JP	A 10-222694	8/1998
JP	A 11-242753	9/1999
JP	A 2000-251090	9/2000
WO	WO 00/25269 A1	5/2000
WO	WO 00/52640 A1	9/2000

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(57) **ABSTRACT**

It is an object to provide an image generating system and program which can generate such an image as in the real world with reduced processing load. The alpha-value for each pixel in the original image is set to a value corresponding to its Z-value. The set alpha-value is used to perform alpha-blending between the original image and a defocused image. As the difference between the Z-value of the focus and the depth value increases, the synthesis ratio of the defocused image is increased. The range of depth of field and defocusing effect are controlled by varying the corresponding relationship between the Z-value and the alpha-value. The alpha-value is set such that the alpha-value for an pixel located in an area AR1 between Z1 and Z2 will be set to α**1**, the alpha-value for an pixel located in an area AR2 between Z2 and Z3 will be set to α**2** and so forth. The alpha-value is set by updating the alpha-value of a pixel located farther from an object when the object is drawn in a frame buffer. When the original image is set as a texture which is in turn mapped through the bi-linear filtering method, the defocused image is generated by shifting the texture coordinates by a value smaller than one texel.

16 Claims, 18 Drawing Sheets

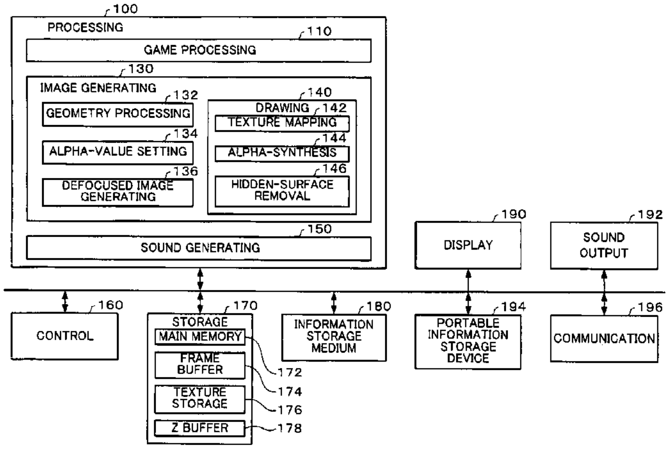


FIG. 1

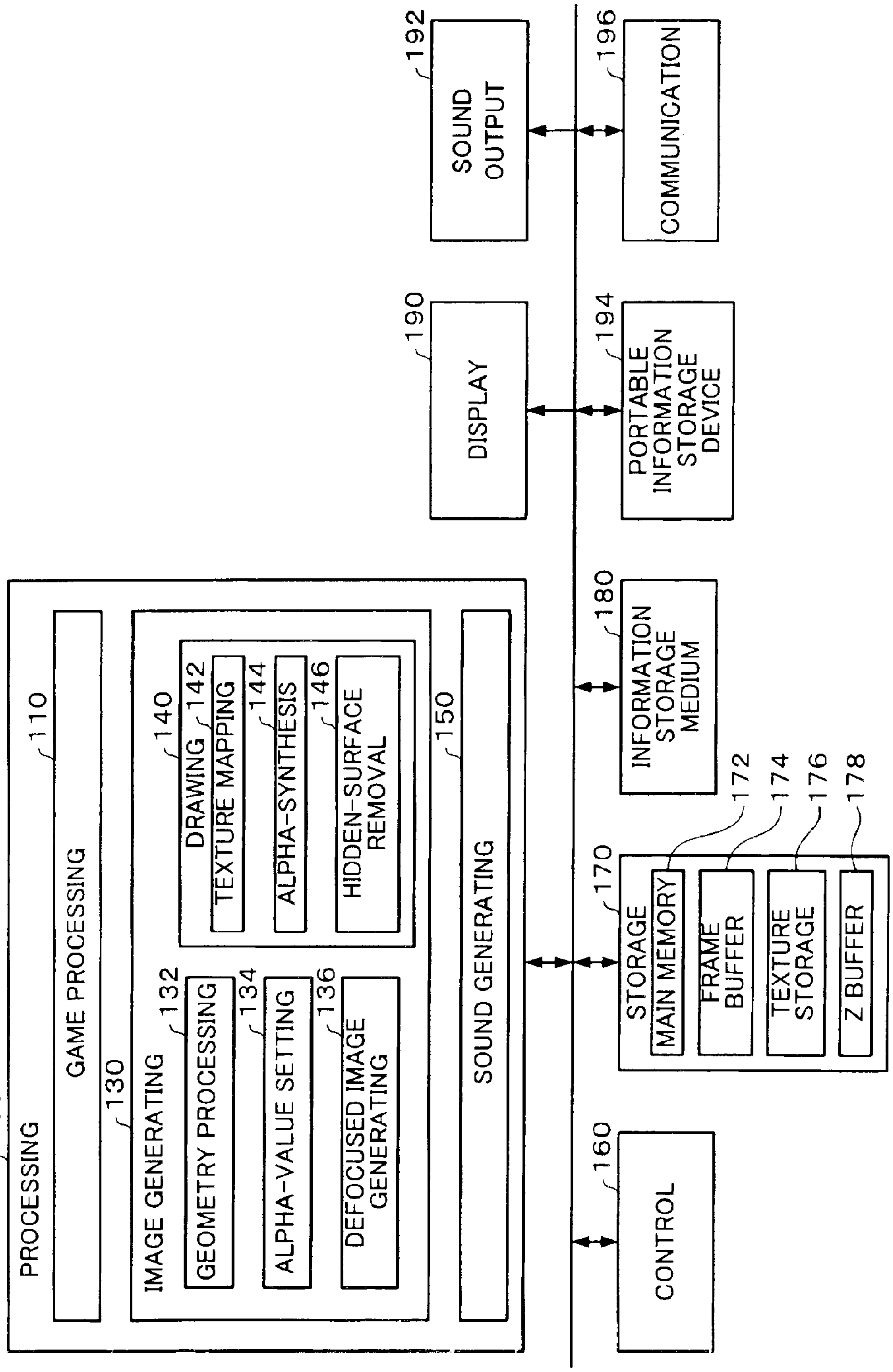

100
PROCESSING
110
GAME PROCESSING
130
IMAGE GENERATING
132
GEOMETRY PROCESSING
134
ALPHA-VALUE SETTING
136
DEFOCUSED IMAGE GENERATING
140
DRAWING
142
TEXTURE MAPPING
144
ALPHA-SYNTHESIS
146
HIDDEN-SURFACE REMOVAL
150
SOUND GENERATING
160
CONTROL
170
STORAGE
172
MAIN MEMORY
174
FRAME BUFFER
176
TEXTURE STORAGE
178
Z BUFFER
180
INFORMATION STORAGE MEDIUM
190
DISPLAY
192
SOUND OUTPUT
194
PORTABLE INFORMATION STORAGE DEVICE
196
COMMUNICATION

FIG. 2

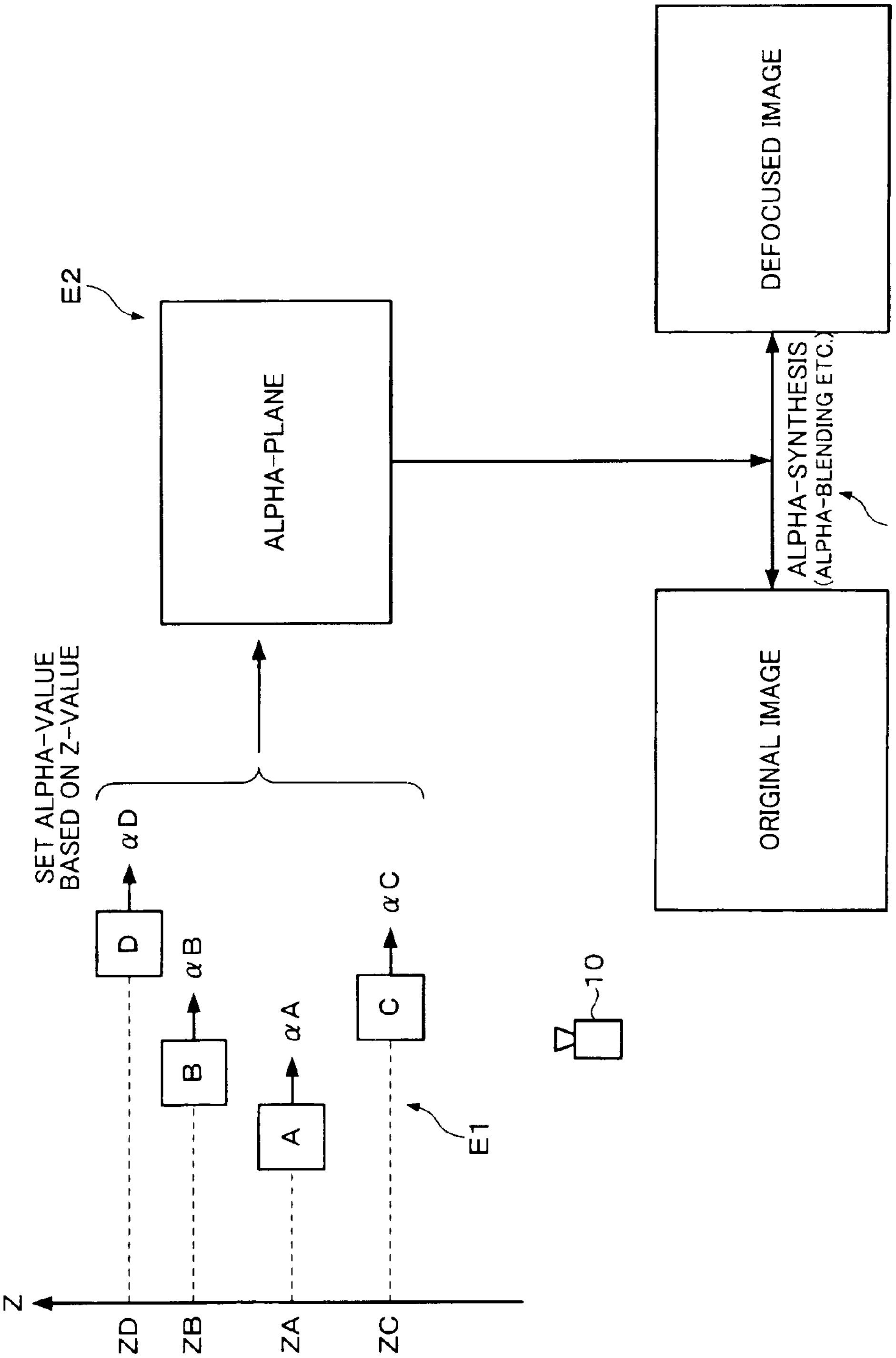

Z
ZD
ZB
ZA
ZC
D
B
A
C
αD
αB
αA
αC
E1
10
SET ALPHA-VALUE
BASED ON Z-VALUE
ALPHA-PLANE
E2
ORIGINAL IMAGE
DEFOCUSED IMAGE
ALPHA-SYNTHESIS
(ALPHA-BLENDING ETC.)
E3

FIG. 3A ORIGINAL IMAGE

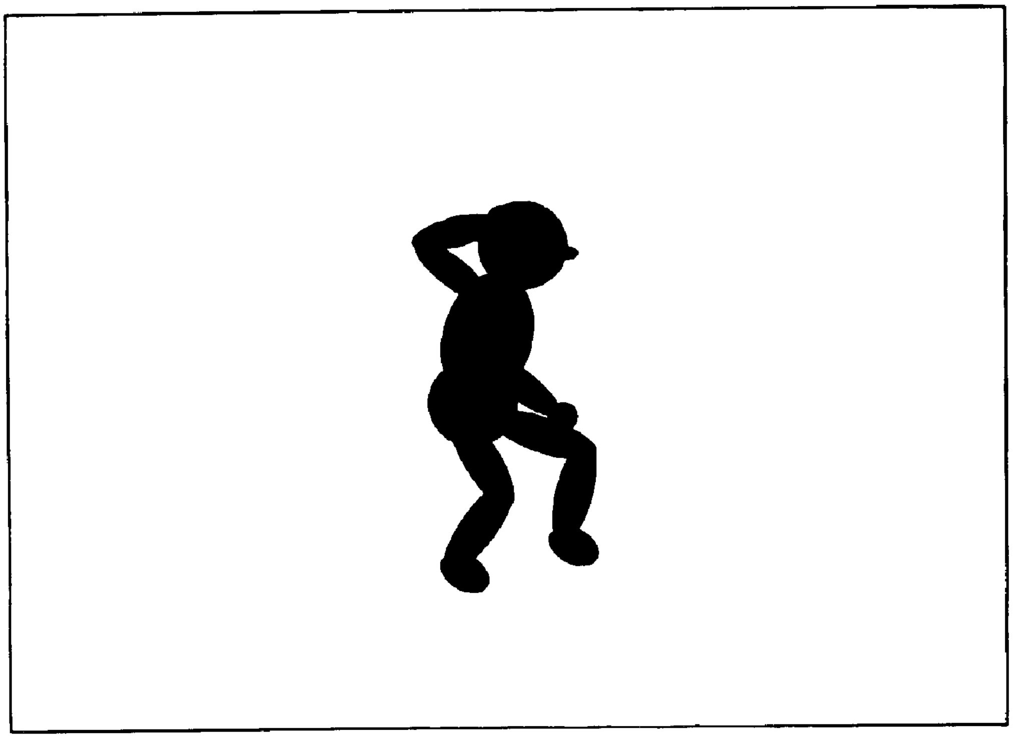


FIG. 3B DEFOCUSED IMAGE

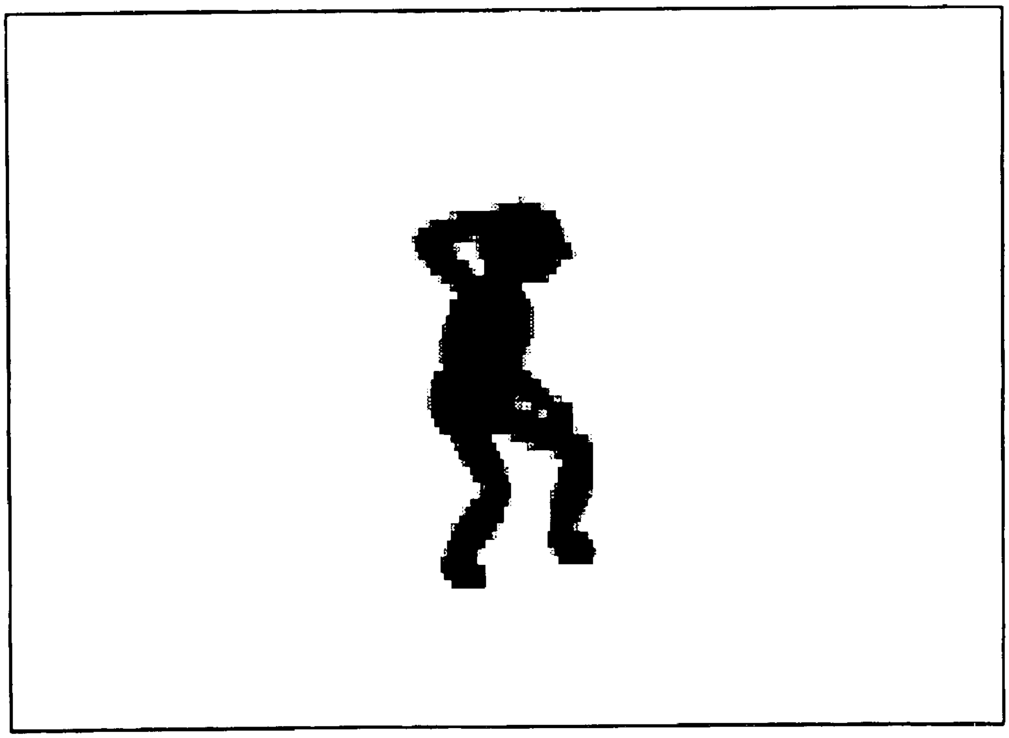


FIG. 4A

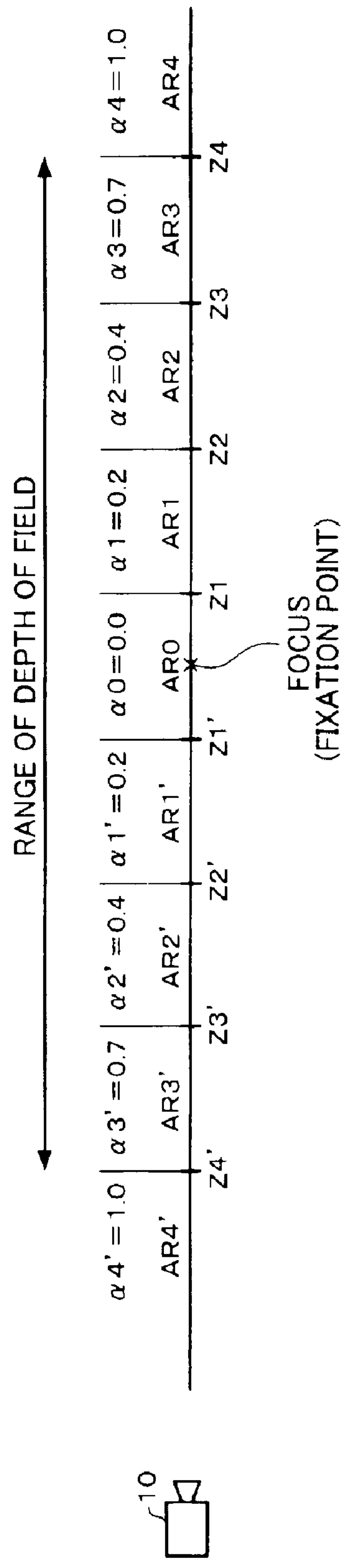

RANGE OF DEPTH OF FIELD
α4'=1.0
AR4'
Z4'
α3'=0.7
AR3'
Z3'
α2'=0.4
AR2'
Z2'
α1'=0.2
AR1'
Z1'
α0=0.0
AR0
Z1
α1=0.2
AR1
Z2
α2=0.4
AR2
Z3
α3=0.7
AR3
Z4
α4=1.0
AR4
FOCUS
(FIXATION POINT)
10

FIG. 4B

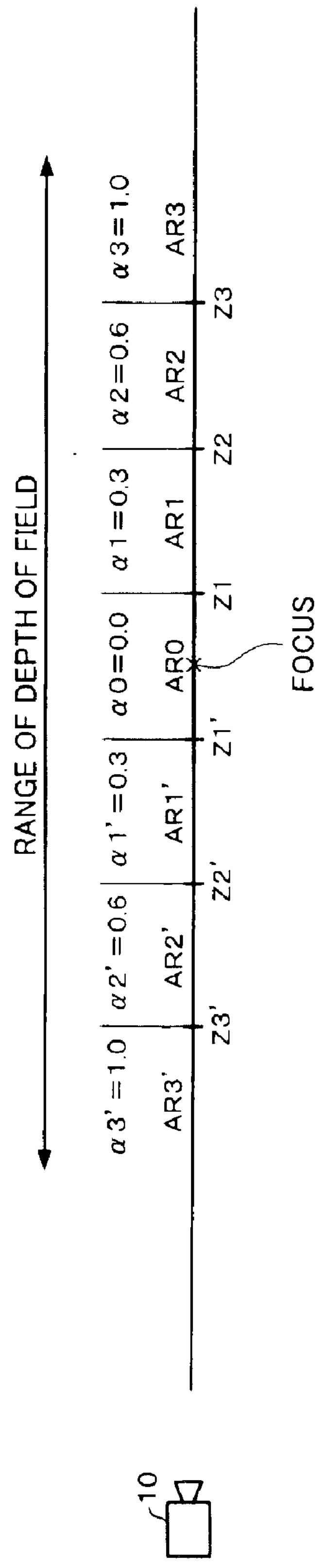

RANGE OF DEPTH OF FIELD
α3'=1.0
AR3'
Z3'
α2'=0.6
AR2'
Z2'
α1'=0.3
AR1'
Z1'
α0=0.0
AR0
Z1
α1=0.3
AR1
Z2
α2=0.6
AR2
Z3
α3=1.0
AR3
FOCUS
10

FIG. 5A

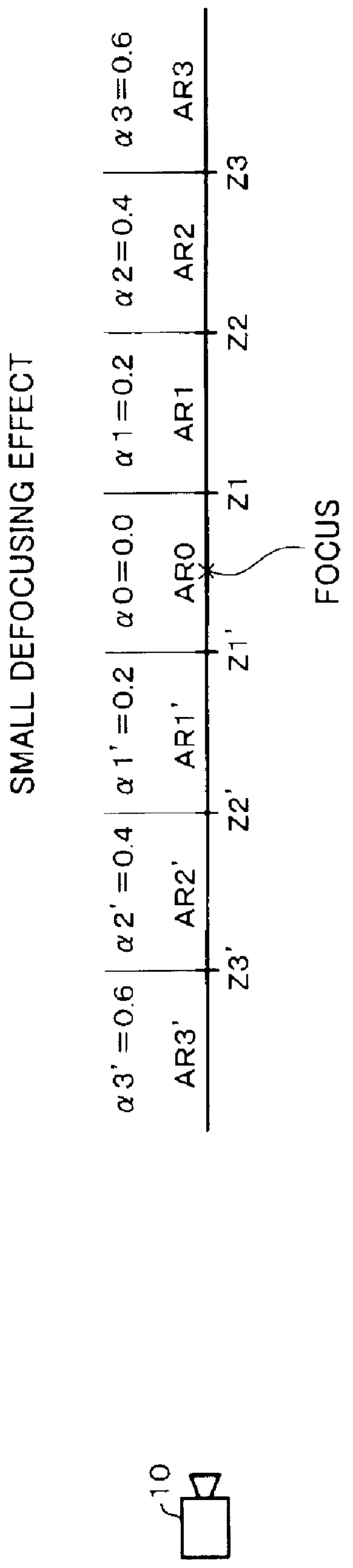

SMALL DEFOCUSING EFFECT
α3'=0.6
AR3'
α2'=0.4
AR2'
α1'=0.2
AR1'
α0=0.0
AR0
α1=0.2
AR1
α2=0.4
AR2
α3=0.6
AR3
Z3'
Z2'
Z1'
Z1
Z2
Z3
FOCUS
10

FIG. 5B

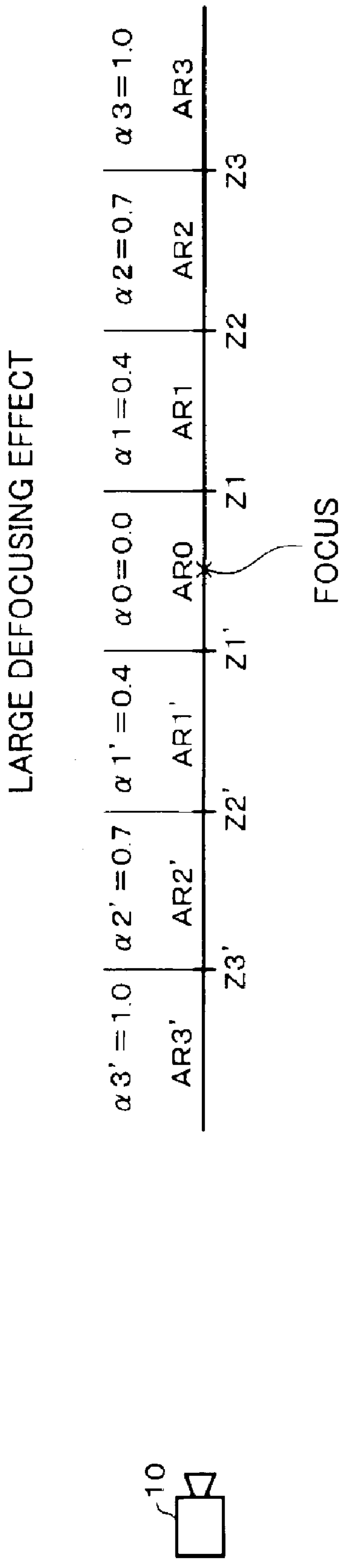

LARGE DEFOCUSING EFFECT
α3'=1.0
AR3'
α2'=0.7
AR2'
α1'=0.4
AR1'
α0=0.0
AR0
α1=0.4
AR1
α2=0.7
AR2
α3=1.0
AR3
Z3'
Z2'
Z1'
Z1
Z2
Z3
FOCUS
10

FIG. 6A

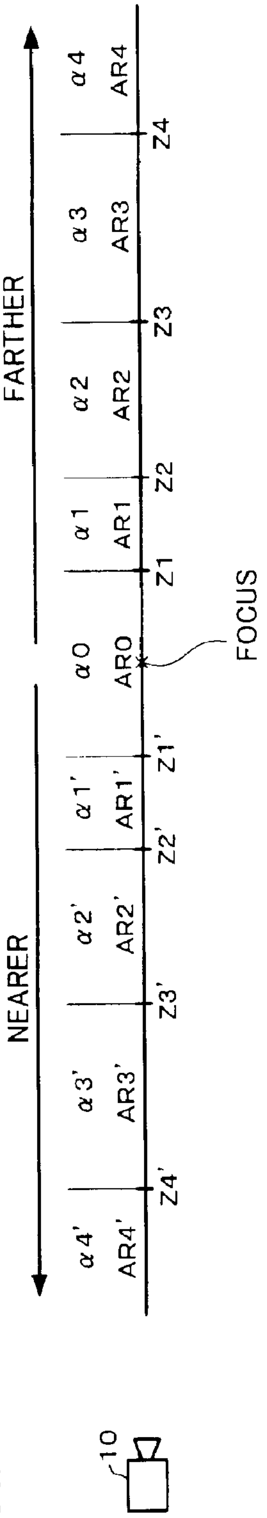


FIG. 6B

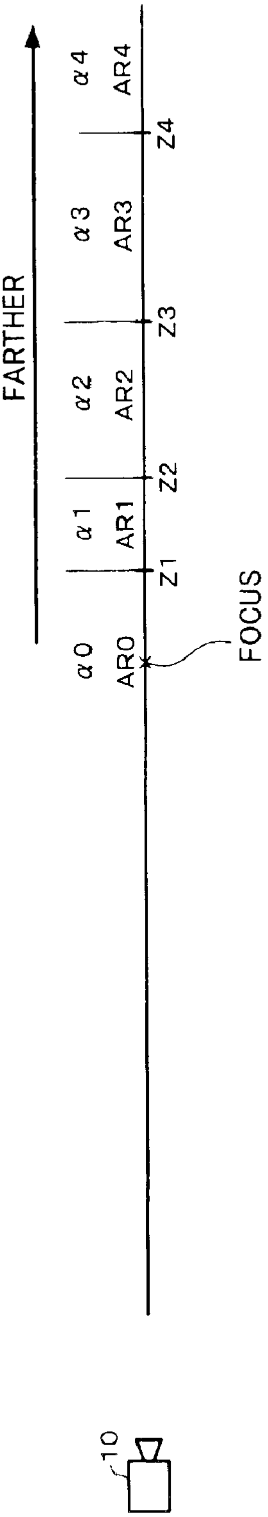
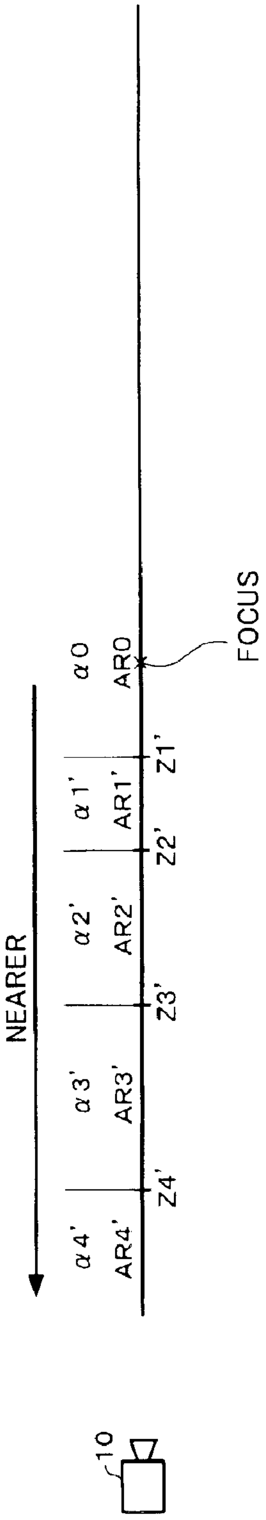


FIG. 6C



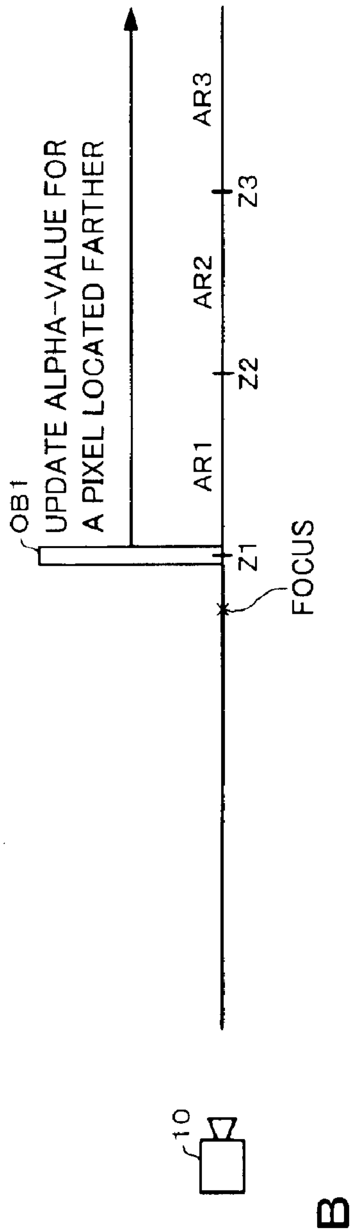


FIG. 7A

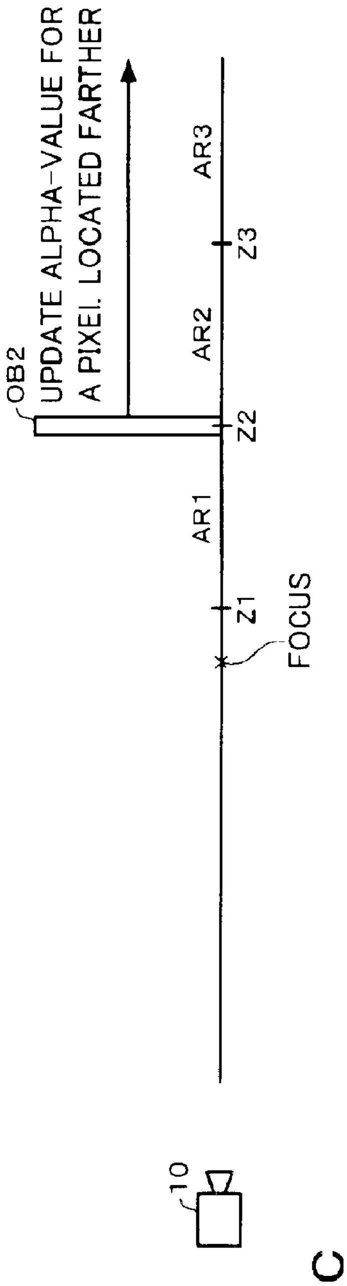


FIG. 7B

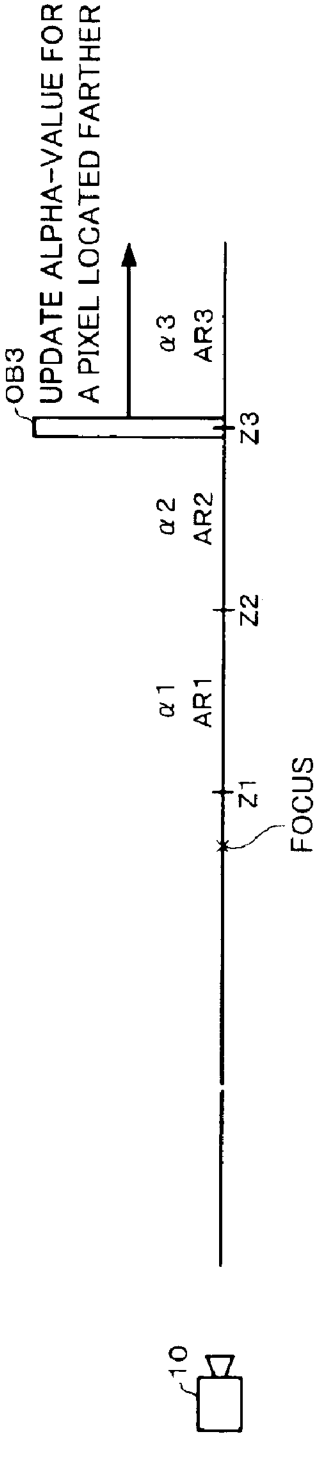


FIG. 7C

FIG. 8A

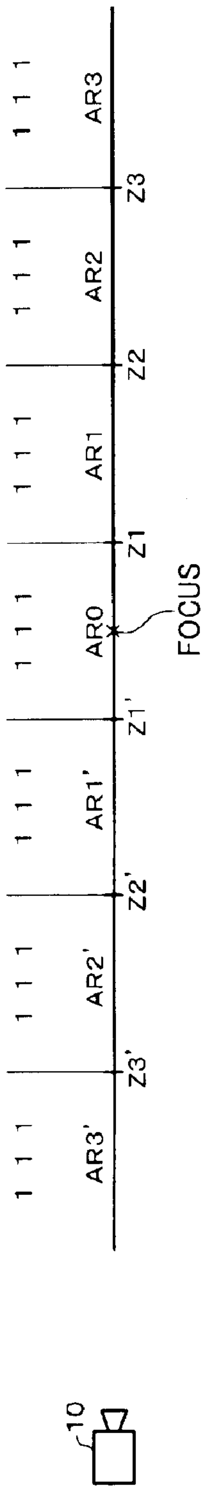


FIG. 8B

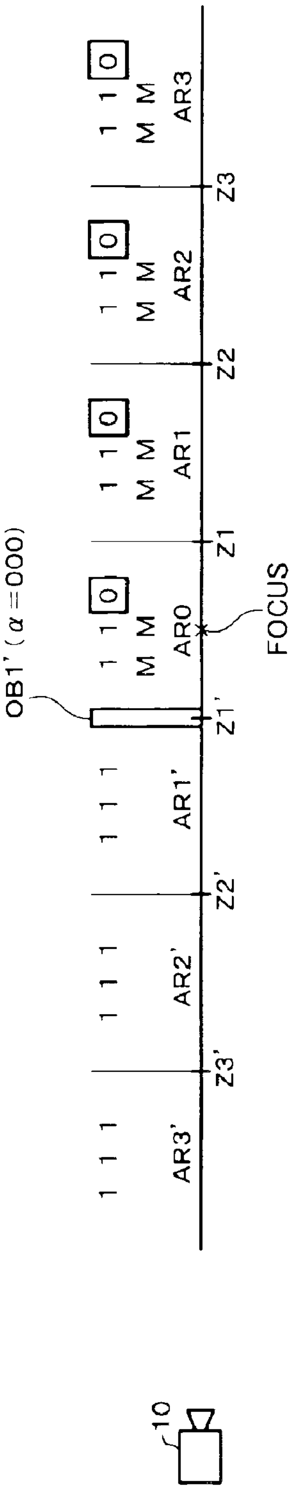


FIG. 8C

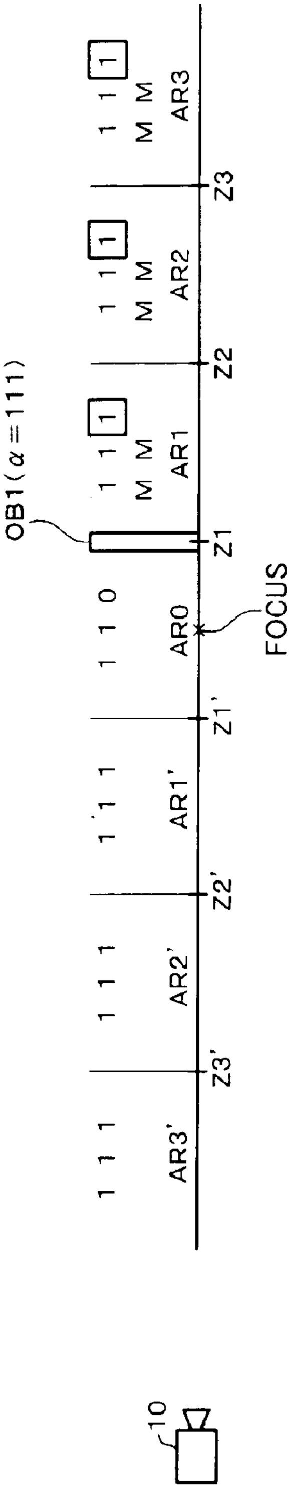


FIG. 9A

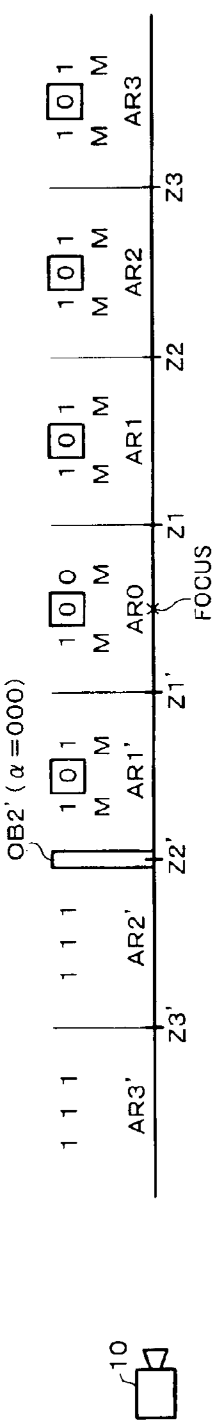


FIG. 9B

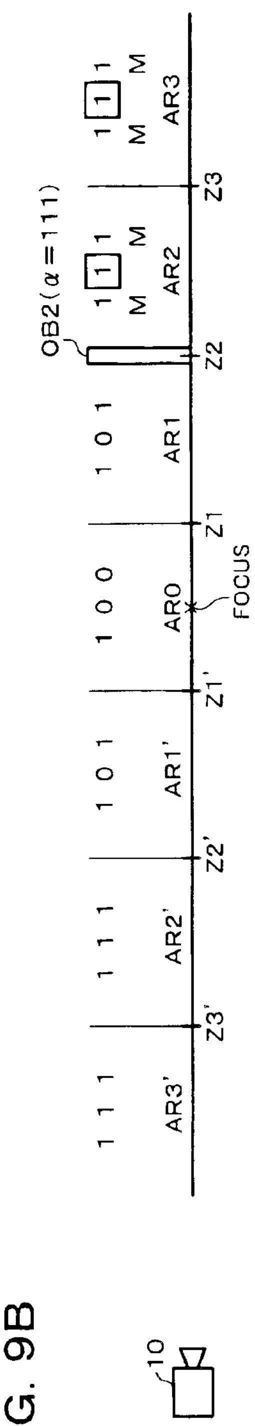


FIG. 9C

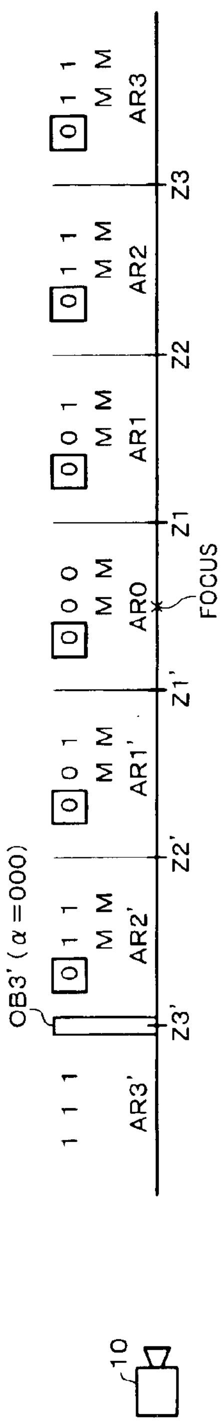


FIG. 9D

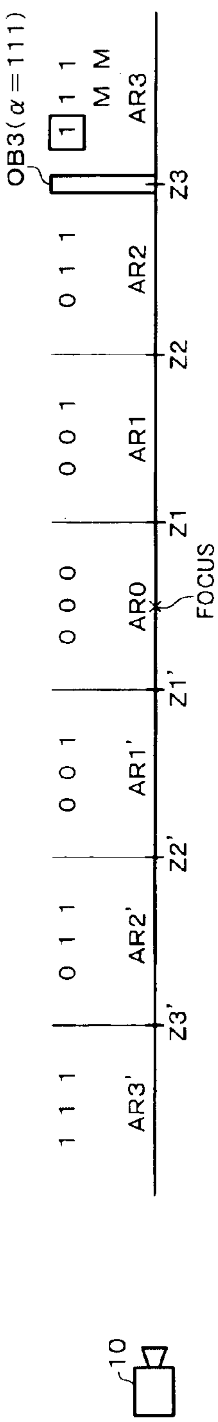
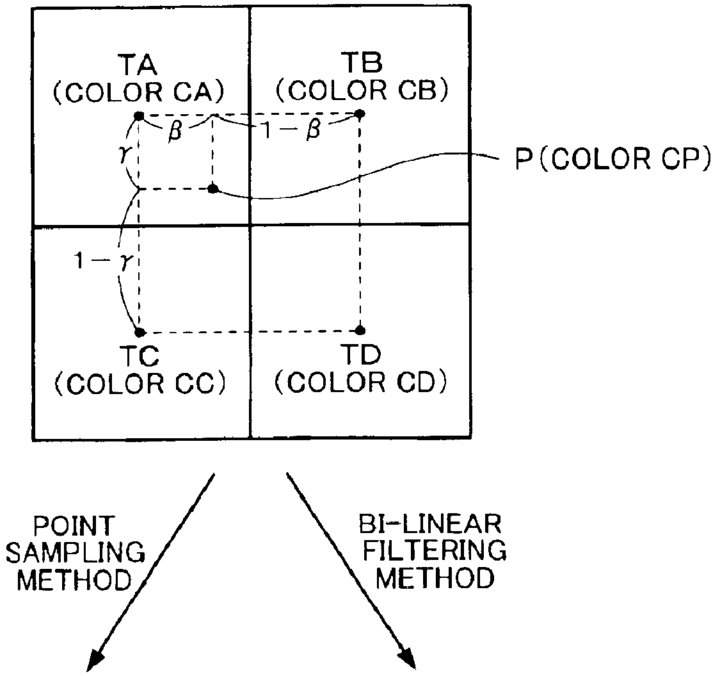


FIG. 10



$CP=CA$

$$CP=(1-\beta)\times(1-\gamma)\times CA+\beta\times(1-\gamma)\times CB$$
$$+(1-\beta)\times\gamma\times CC+\beta\times\gamma\times CD$$

FIG. 11

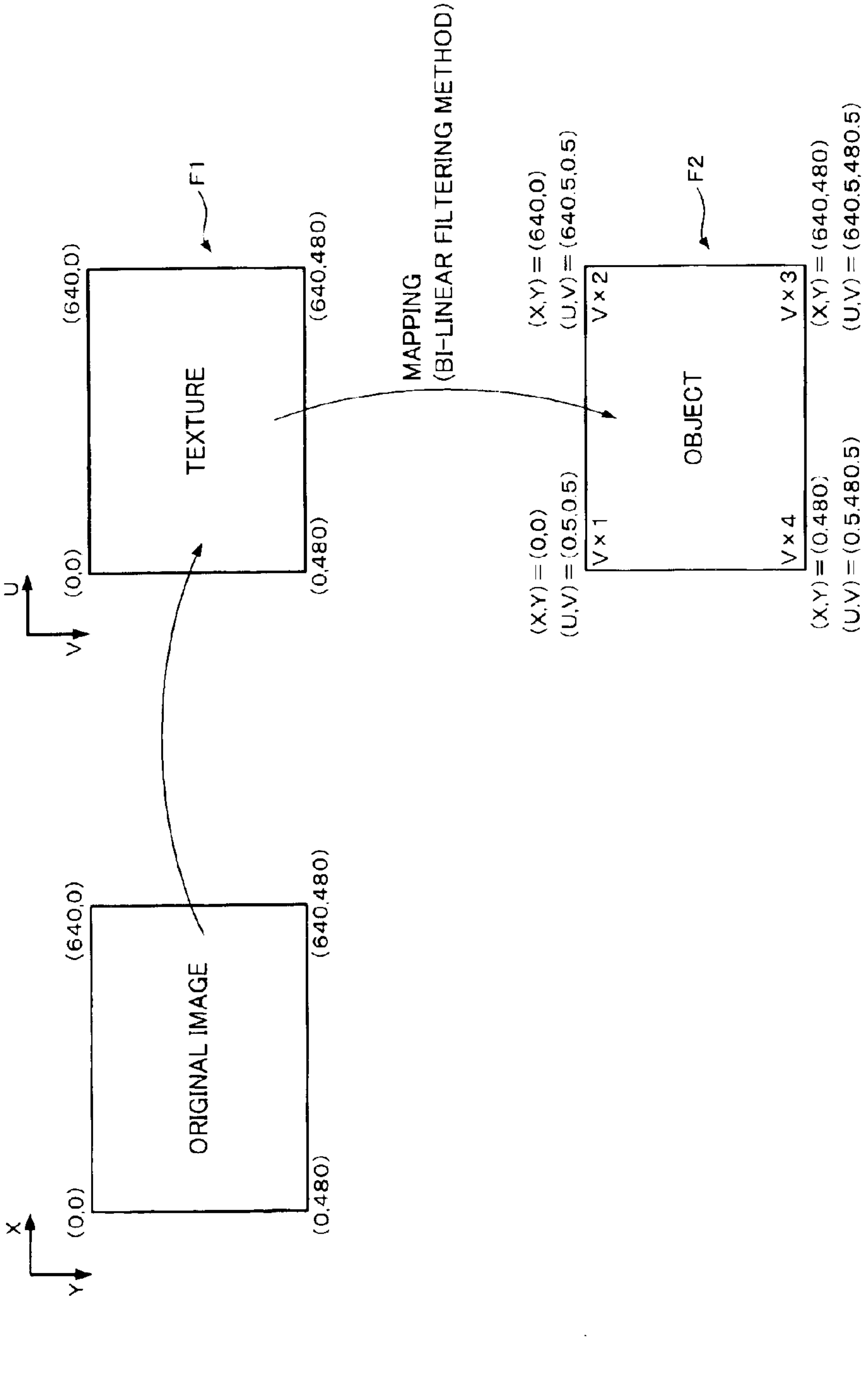

Y
X
(0,0)
(640,0)
ORIGINAL IMAGE
(0,480)
(640,480)
V
U
(0,0)
(640,0)
TEXTURE
(0,480)
(640,480)
F1
MAPPING
(BI-LINEAR FILTERING METHOD)
(X,Y)=(0,0)
(U,V)=(0.5,0.5)
V×1
(X,Y)=(640,0)
(U,V)=(640.5,0.5)
V×2
F2
OBJECT
V×4
(X,Y)=(0,480)
(U,V)=(0.5,480.5)
V×3
(X,Y)=(640,480)
(U,V)=(640.5,480.5)

FIG. 12

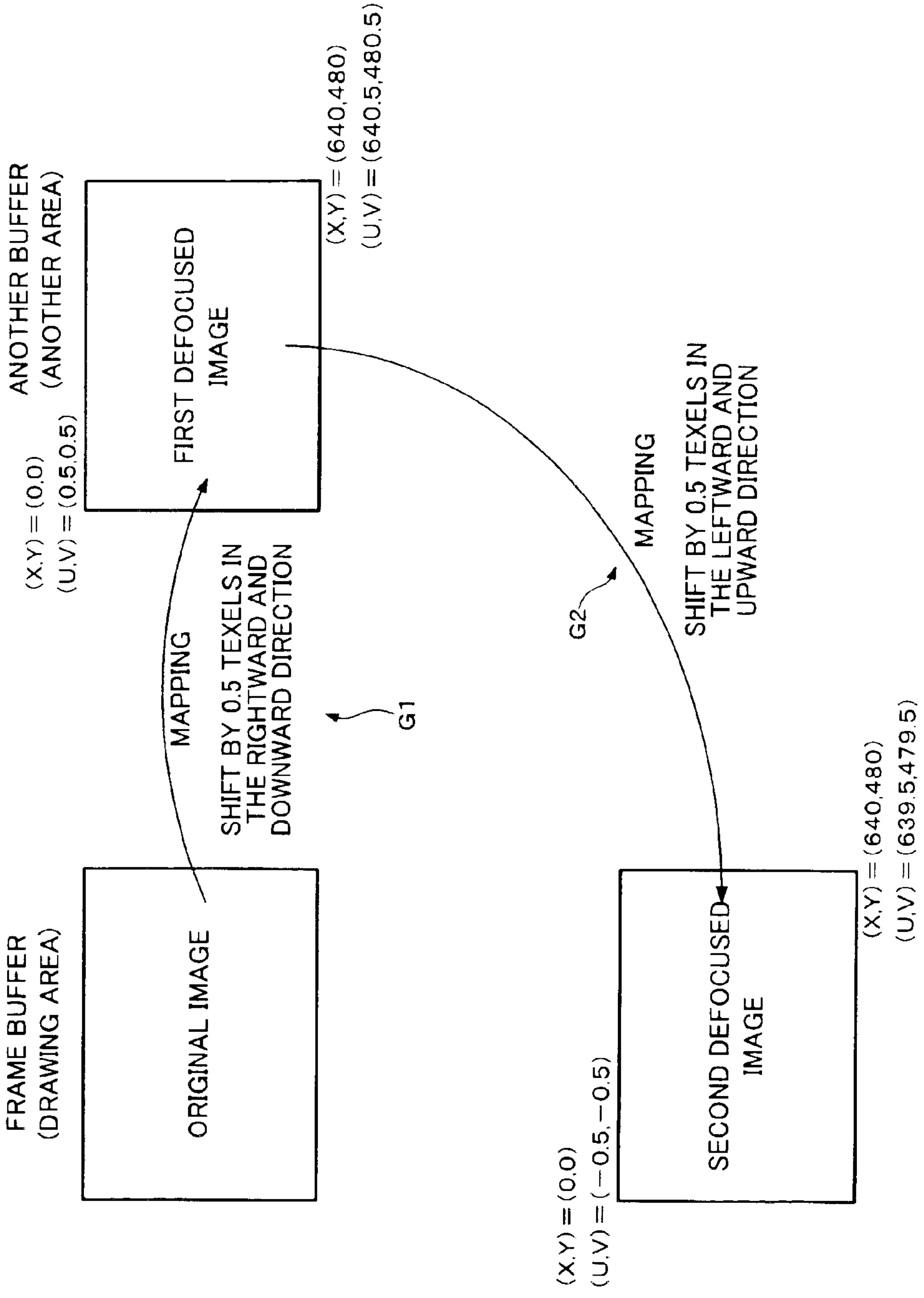

FRAME BUFFER
(DRAWING AREA)
ORIGINAL IMAGE
MAPPING
SHIFT BY 0.5 TEXELS IN THE RIGHTWARD AND DOWNWARD DIRECTION
G1
(X,Y)=(0,0)
(U,V)=(0.5,0.5)
ANOTHER BUFFER
(ANOTHER AREA)
FIRST DEFOCUSED IMAGE
(X,Y)=(640,480)
(U,V)=(640.5,480.5)
MAPPING
SHIFT BY 0.5 TEXELS IN THE LEFTWARD AND UPWARD DIRECTION
G2
(X,Y)=(0,0)
(U,V)=(−0.5,−0.5)
SECOND DEFOCUSED IMAGE
(X,Y)=(640,480)
(U,V)=(639.5,479.5)

FIG. 13A

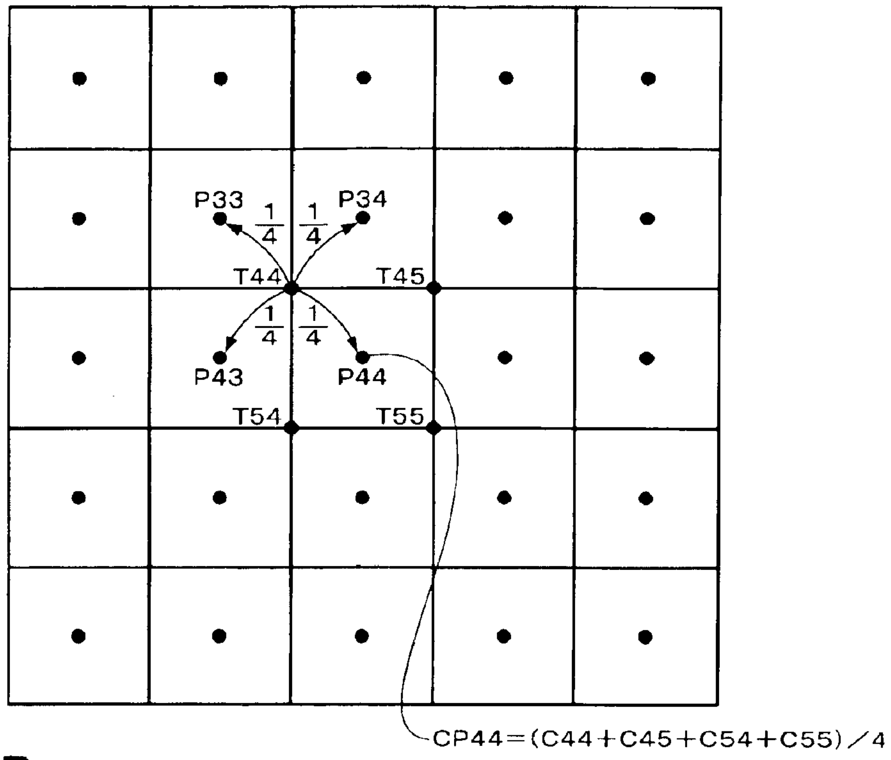


FIG. 13B

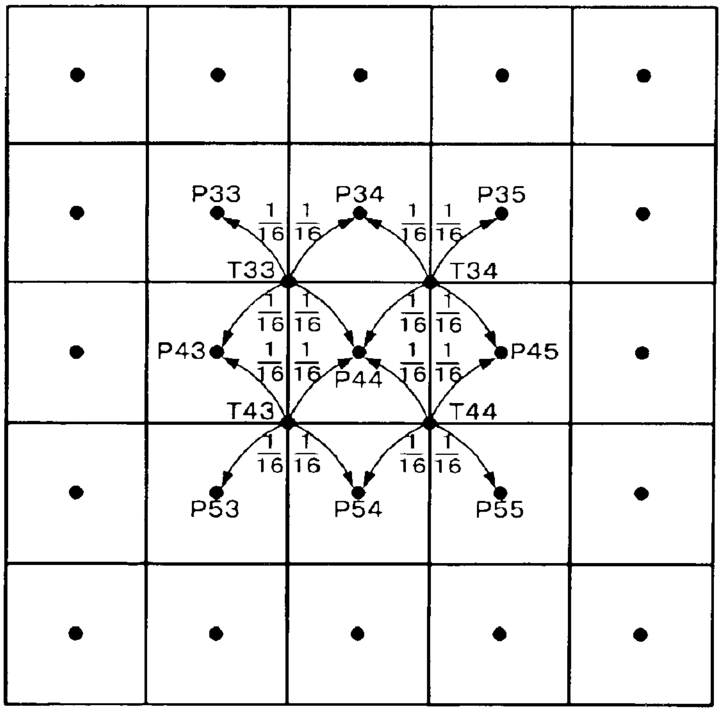


FIG. 14A

	$\frac{1}{16}$	$\frac{2}{16}$	$\frac{1}{16}$	
	$\frac{2}{16}$	$\frac{4}{16}$	$\frac{2}{16}$	
	$\frac{1}{16}$	$\frac{2}{16}$	$\frac{1}{16}$	

FIG. 14B

$\frac{1}{256}$	$\frac{4}{256}$	$\frac{6}{256}$	$\frac{4}{256}$	$\frac{1}{256}$
$\frac{4}{256}$	$\frac{16}{256}$	$\frac{24}{256}$	$\frac{16}{256}$	$\frac{4}{256}$
$\frac{6}{256}$	$\frac{24}{256}$	$\frac{36}{256}$	$\frac{24}{256}$	$\frac{6}{256}$
$\frac{4}{256}$	$\frac{16}{256}$	$\frac{24}{256}$	$\frac{16}{256}$	$\frac{4}{256}$
$\frac{1}{256}$	$\frac{4}{256}$	$\frac{6}{256}$	$\frac{4}{256}$	$\frac{1}{256}$

FIG. 15

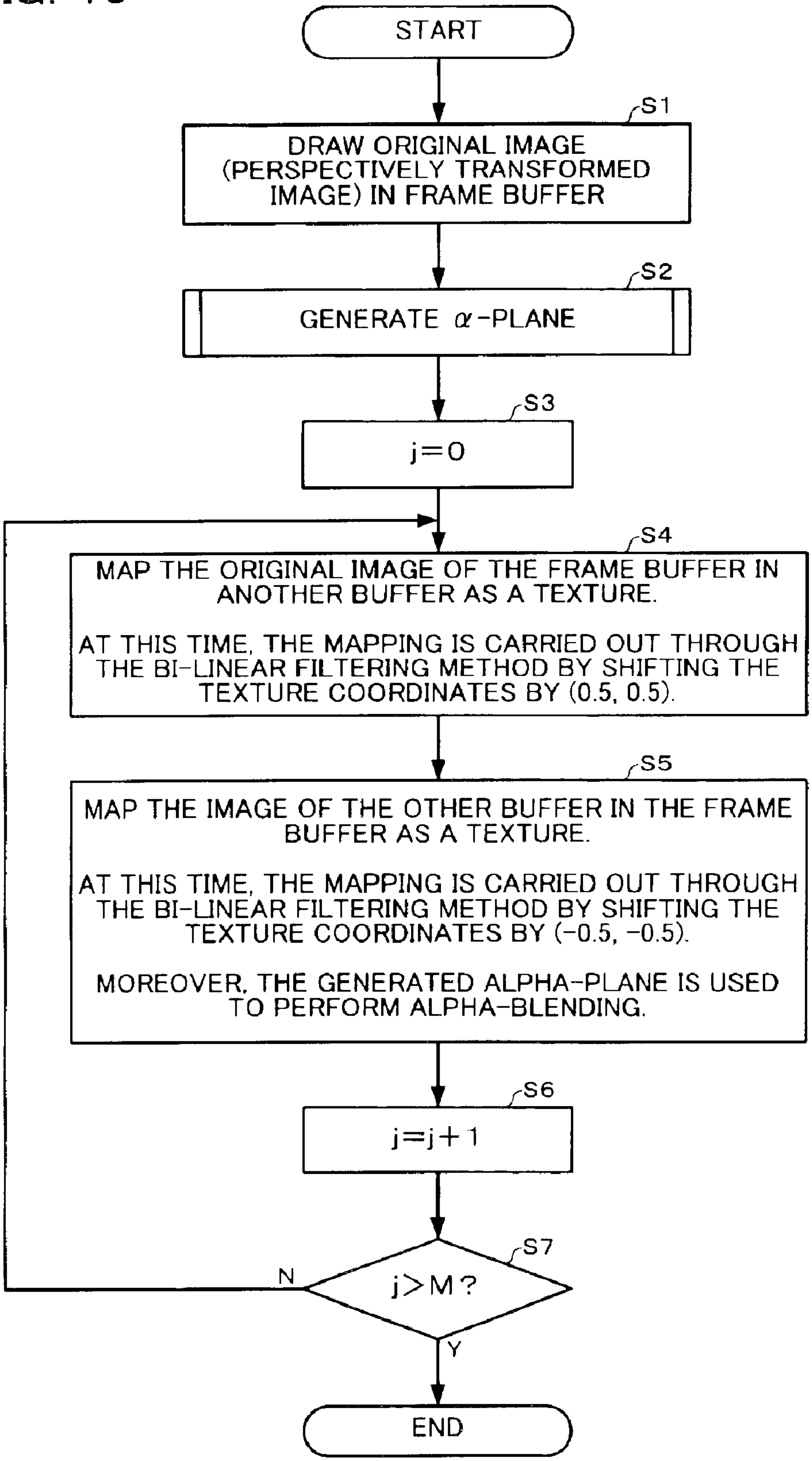

START
S1
DRAW ORIGINAL IMAGE (PERSPECTIVELY TRANSFORMED IMAGE) IN FRAME BUFFER
S2
GENERATE α-PLANE
S3
j=0
S4
MAP THE ORIGINAL IMAGE OF THE FRAME BUFFER IN ANOTHER BUFFER AS A TEXTURE.
AT THIS TIME, THE MAPPING IS CARRIED OUT THROUGH THE BI-LINEAR FILTERING METHOD BY SHIFTING THE TEXTURE COORDINATES BY (0.5, 0.5).
S5
MAP THE IMAGE OF THE OTHER BUFFER IN THE FRAME BUFFER AS A TEXTURE.
AT THIS TIME, THE MAPPING IS CARRIED OUT THROUGH THE BI-LINEAR FILTERING METHOD BY SHIFTING THE TEXTURE COORDINATES BY (−0.5, −0.5).
MOREOVER, THE GENERATED ALPHA-PLANE IS USED TO PERFORM ALPHA-BLENDING.
S6
j=j+1
S7
j>M?
N
Y
END

FIG. 16

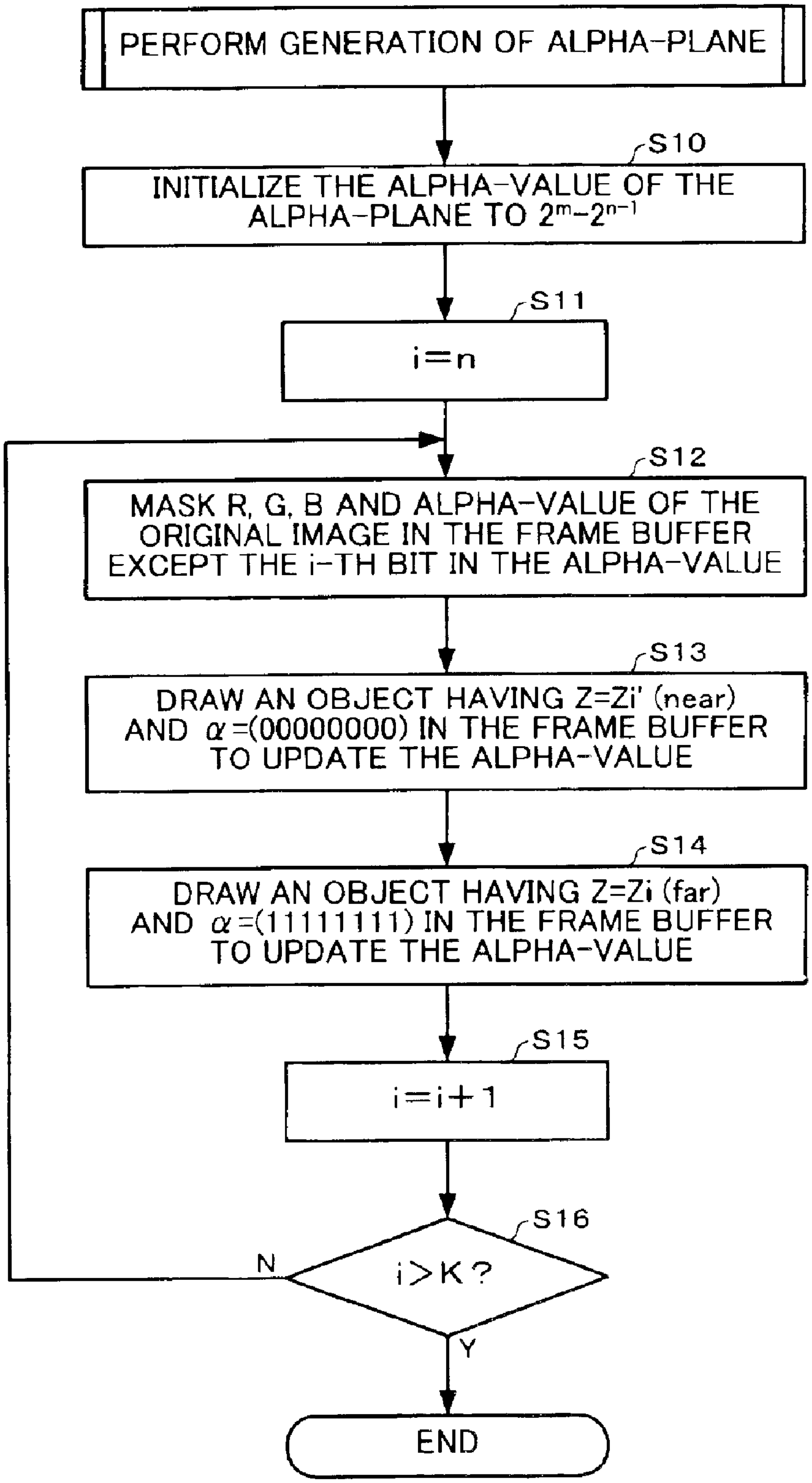

PERFORM GENERATION OF ALPHA-PLANE
S10
INITIALIZE THE ALPHA-VALUE OF THE ALPHA-PLANE TO 2^m-2^{n-1}
S11
i=n
S12
MASK R, G, B AND ALPHA-VALUE OF THE ORIGINAL IMAGE IN THE FRAME BUFFER EXCEPT THE i-TH BIT IN THE ALPHA-VALUE
S13
DRAW AN OBJECT HAVING Z=Zi' (near) AND α=(00000000) IN THE FRAME BUFFER TO UPDATE THE ALPHA-VALUE
S14
DRAW AN OBJECT HAVING Z=Zi (far) AND α=(11111111) IN THE FRAME BUFFER TO UPDATE THE ALPHA-VALUE
S15
i=i+1
S16
i>K?
N
Y
END

FIG. 17

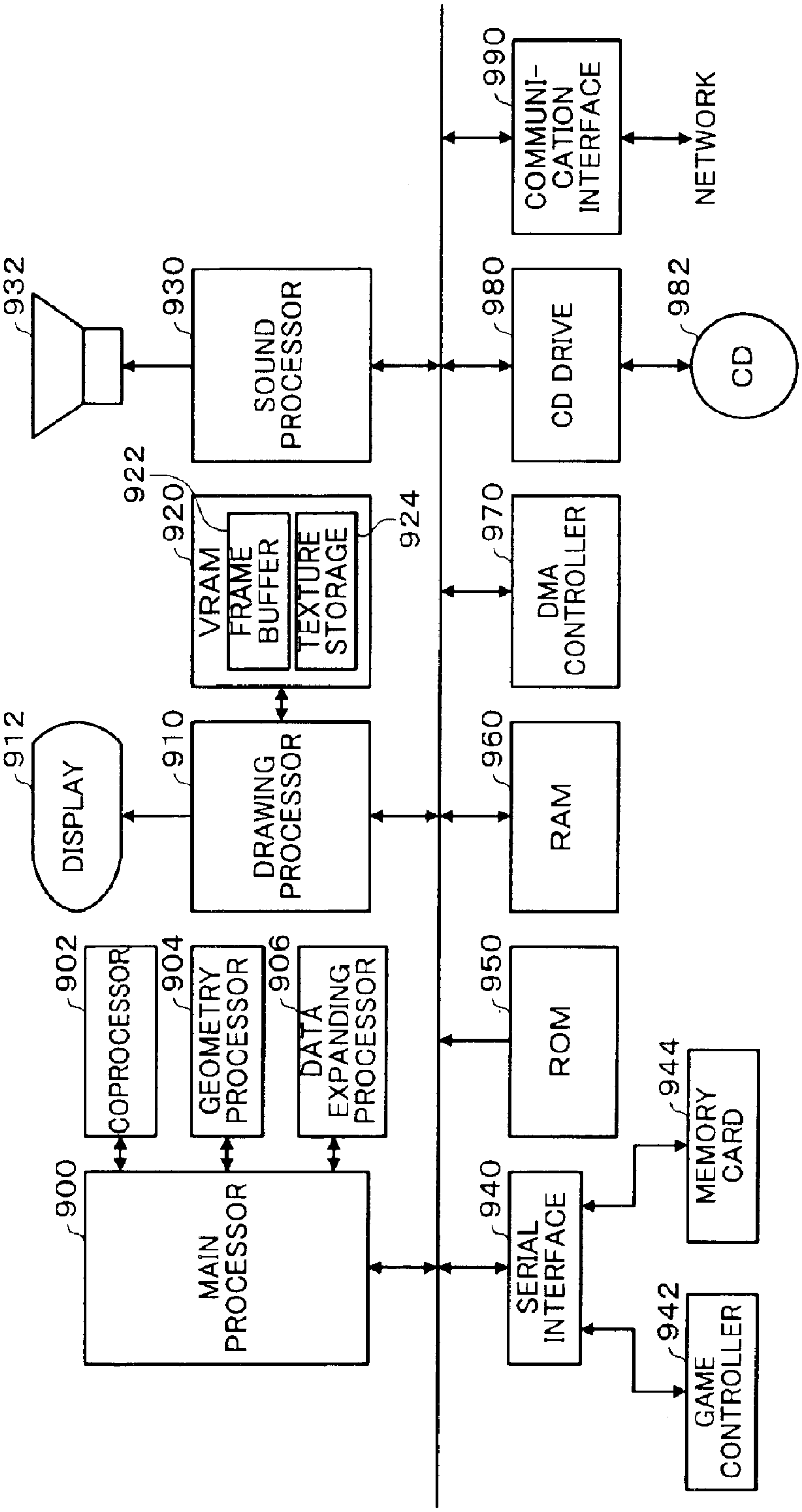

900
MAIN PROCESSOR
902
COPROCESSOR
904
GEOMETRY PROCESSOR
906
DATA EXPANDING PROCESSOR
910
DRAWING PROCESSOR
912
DISPLAY
920
VRAM
922
FRAME BUFFER
924
TEXTURE STORAGE
930
SOUND PROCESSOR
932
940
SERIAL INTERFACE
942
GAME CONTROLLER
944
MEMORY CARD
950
ROM
960
RAM
970
DMA CONTROLLER
980
CD DRIVE
982
CD
990
COMMUNI-CATION INTERFACE
NETWORK

FIG. 18A

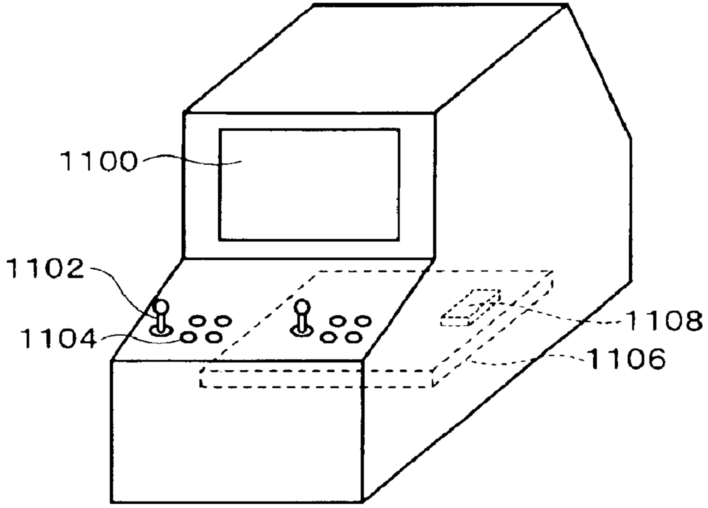


FIG. 18B

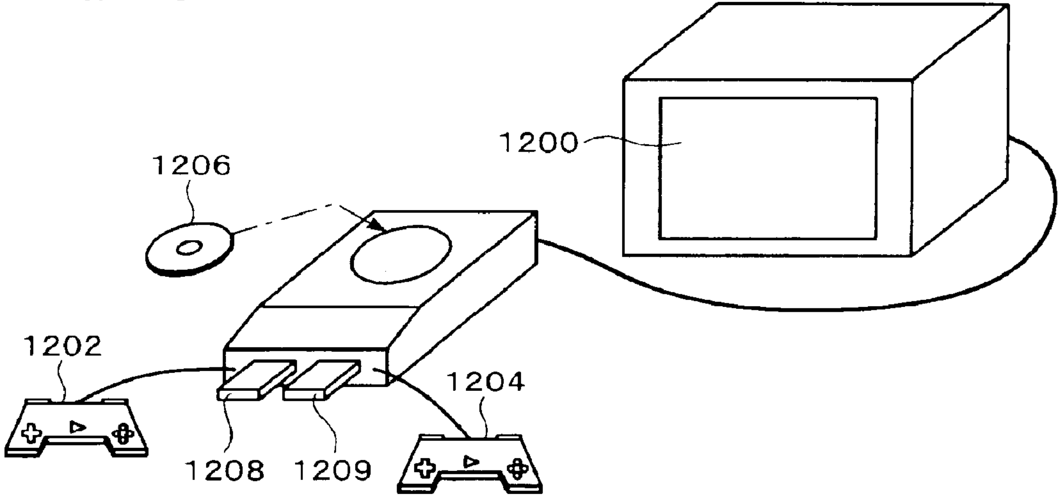


FIG. 18C

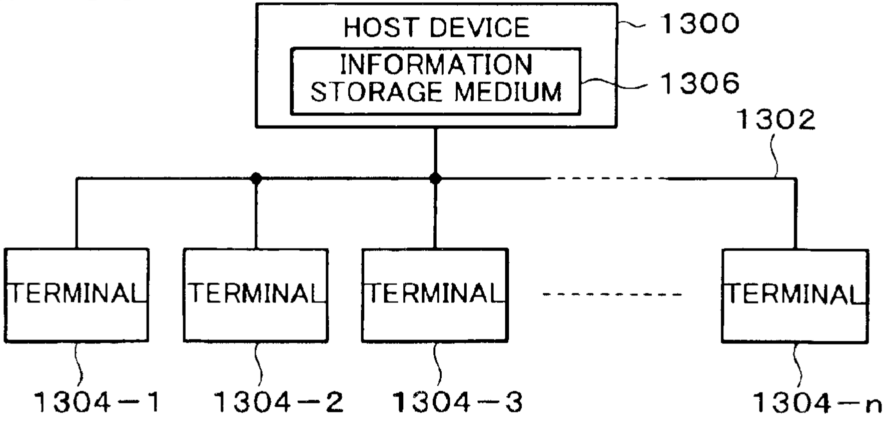


IMAGE GENERATING SYSTEM AND PROGRAM

TECHNICAL FIELD

The present invention relates to an image generating system and program.

BACKGROUND OF ART

In the prior art, there is known an image generating system which can generate an image viewable from a given viewpoint in an object space that is a virtual three-dimensional space. Such an image generating system is very popular as a system which can realize a so-called virtual reality. If the image generating system is for a racing game, a player can enjoy a three-dimensional game by controlling and running a racing car (or object) in the object space to compete with the other racing cars controlled by the other players or computer.

However, an image generated by the prior art image generating system will not be focused depending on the distance from a viewpoint as in the actual human view. Thus, the representation is such that all the subjects within the image are in focus.

The image in which all the subjects ranging between the short distance and the long distance are in focus is abnormal in our daily life.

To pursue the reality, it is desirable that an image is generated in which a focus is regulated depending on the distance between the viewpoint and an object or the direction of sight line. However, the processing load will be increased if a defocused image is generated by calculating the distance between an individual object and the viewpoint within a game space to process the degree of defocusing for each object.

In an image generating system which must generate an image corresponding to a real-time variable viewpoint using its limited hardware resource, it is important that a focused image as in the actual world can be generated using less processing load.

DISCLOSURE OF INVENTION

To overcome such a problem in the prior art, an object of the present invention is to provide an image generating system and program which can generate a focused image as in the actual world with less processing load.

To this end, the present invention provides an image generating system for generating an image, comprising: alpha-value setting means which sets an alpha-value for each pixel to a value corresponding to a depth value of the each pixel in an original image; and means for synthesizing the original image with a defocused image corresponding to the original image based on the alpha-value set for each pixel. The present invention also provides a computer-usable information storage medium including a program for realizing the above-described means. The present invention further provides a computer-usable program (including a program embodied in a carrier wave) which includes a processing routine for realizing the above-described means.

According to the present invention, the original image is synthesized with the defocused image based on the set alpha-value corresponding to the depth value for each pixel in the original image. Thus, the synthesis ratio and the like in the defocused image is variable depending on the depth value. Therefore, the depth of field may be represented, for example.

The alpha(α)-value is information stored in association with each pixel and may be information other than color information, for example. The depth value may be increased as the pixel moves faraway from or close to the viewpoint (or virtual camera). The technique of synthesizing the original image with the defocused image may be any of various known techniques. The synthesizing process using the alpha-value is not limited to the alpha-blending.

In the image generating system, information storage medium and program according to the present invention, the alpha-value setting means may set the alpha-value for the each pixel so that a synthesis ratio of the defocused image becomes higher for a pixel having a larger difference between a focal depth value of a virtual camera and the depth value of the each pixel.

In such a manner, such an image that is defocused as it is spaced faraway from the focus can be generated.

If the synthesis ratio of the defocused image increases as the alpha-value increases, the alpha-value may be increased as the difference between the depth value of the pixel and that of the focus increases. On the contrary, if the synthesis ratio of the defocused image increases as the alpha-value decreases, the alpha-value may be decreased as the difference between the depth value of the pixel and that of the focus increases.

In the image generating system, information storage medium and program according to the present invention, a range of depth of field or magnitude of defocusing effect may be variably controlled by varying a corresponding relationship between the depth value of the each pixel and the alpha-value.

Thus, an image in which the range of depth of field or the magnitude defocusing effect is variable can be generated merely by varying the corresponding relationship between the depth value and the alpha-value. This improves the variety in the representation of image.

The range of depth of field is not limited to any particular range, but maybe a range between the nearest and farthest points in which a focused clear image may be obtained. For example, the range of depth of field may be defined to be a range in which the alpha-value becomes smaller than a given value or larger than a given value. The control of the magnitude of the defocusing effect may be realized, for example, by utilizing the same depth value varying the magnitude of the alpha-value.

The present invention further provides an image generating system for generating an image, comprising: alpha-value setting means which sets an alpha-value for a pixel having a depth value located in an area **AR1** between **Z1** and **Z2** as α**1**, the alpha-value for a pixel having a depth value located in an area **AR2** between **Z2** and **Z3** as α**2**, . . . , and subsequently the alpha-value for a pixel having a depth value located in an area ARi between Zi and Zi+**1** as αi; and means for drawing an image based on the alpha-value set by the alpha-value setting means. The present invention further provides a computer-usable information storage medium including a program for realizing the above-described means. The present invention further provides a computer-usable program (including a program embodied in a carrier wave) which includes a processing routine for realizing the above-described means.

According to the present invention, the alpha-values for the pixels located at the areas **AR1**, **AR2**, to ARi are set into α**1**, α**2**, to αi, respectively. The alpha-values α**1**, α**2**, to αi thus set are used to draw the image. Thus, the alpha-value may simply be set depending on the associated depth value.

The corresponding relationship between the depth value and the alpha-value may also variably be controlled in a simple manner.

The drawing process based on the alpha-value set by the present invention is not limited to the synthesizing of the original image with the defocused image.

In the image generating system, information storage medium and program according to the present invention, the alpha-value setting means may update: the alpha-value of an pixel located in a first direction from an object OB**1** having the depth value set as Z**1** by drawing the object OB**1** in a drawing area of an original image; the alpha-value of an pixel located in the first direction from an object OB**2** having the depth value set as Z**2** by drawing the object OB**2** in the drawing area of the original image; . . . and subsequently the alpha-value of an pixel located in the first direction from an object OBi having the depth value set as Zi by drawing the object OBi in the drawing area of the original image.

In such a manner, the alpha-value can be set depending on the depth value through a light and high-speed process of only drawing objects.

The first direction may be one that extends farther or nearer as viewed from the object.

In the image generating system, information storage medium and program according to the present invention, the alpha-value setting means may update only a bit to be updated by masking a bit not to be updated when an object is drawn in the drawing area of the original image to update the alpha-value.

In such a manner, the alpha-value can be updated in bit unit. It is further desirable that the color or other information for each pixel is masked on updating the alpha-value.

In the image generating system, information storage medium and program according to the present invention, the alpha-value setting means may update: an n-th bit in the alpha-value of a pixel located in a first direction from an object OB**1'** having the depth value set as Z**1'** into a first level by drawing the object OB**1'** in a drawing area of an original image, and the n-th bit in the alpha-value of a pixel located in the first direction from an object OB**1** having the depth value set as Z**1** and located in the first direction from the object OB**1'** into a second level by drawing the object OB**1** in the drawing area of the original image; an (n+1)-th bit in the alpha-value of a pixel located in the first direction from an object OB**2'** having the depth value set as Z**2'** into the first level by drawing the object OB**2'** in the drawing area of the original image, and the (n+1)-th bit in the alpha-value of a pixel located in the first direction from an object OB**2** having the depth value set as Z**2** and located in the first direction from the object OB**2'** into the second level by drawing the object OB**2** in the drawing area of the original image; . . . and an (n+i−1)-th bit in the alpha-value of a pixel located in the first direction from an object OBi' having the depth value set as Zi' into the first level by drawing the object OBi' in the drawing area of the original image, and the (n+i−1)-th bit in the alpha-value of a pixel located in the first direction from an object OBi having the depth value set as Zi and located in the first direction from the object OBi' into the second level by drawing the object OBi in the drawing area of the original image.

The first direction may be one that extends farther or nearer as viewed from the object.

The present invention further provides an image generating system for generating an image, comprising: means for mapping a texture on an object by a texel interpolation method; and means for generating a defocused image for an original image by setting the original image as a texture and shifting a texture coordinate of the object when the texture is mapped on the object by the texel interpolation method. The present invention further provides a computer-usable information storage medium including a program for realizing the above-described means. The present invention further provides a computer-usable program (including a program embodied in a carrier wave) which includes a processing routine for realizing the above-described means.

According to the present invention, the defocused image can be generated through a simplified process by effectively using the texel interpolation method.

The texel interpolation method is not limited to any particular form, but may be a method in which the image information of a pixel can be obtained by interpolating the image information of a texel, for example, such as the bi-linear filtering or tri-linear filtering method.

In the image generating system, information storage medium and program according to the present invention, the defocused image of the original image may be generated by shifting the texture coordinate by a value smaller than one texel.

In the image generating system, information storage medium and program according to the present invention, the texture coordinates may be shifted to a first shift direction to perform the texture mapping by the texel interpolation method and then the texture coordinates may be shifted to a second shift direction to perform the texture mapping by the texel interpolation method.

Thus, a more ideal defocused image can be generated.

It is desirable that the first and second shift directions are opposite to each other. It is further desirable that a plurality of shift sets of the first and second shift directions are repeated.

In the image generating system, information storage medium and program according to the present invention, the object may be a virtual object having a shape substantially equal to a shape of a defocused area.

If the entire image is to be defocused, it is desirable that the objects and defocused area have the same shape as that of the screen. However, only part of the screen area may be defocused.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of an image generating system according to this embodiment.

FIG. **2** illustrates a technique of setting an alpha-value corresponding to Z-value (depth value) and using the set alpha-value to synthesize a defocused image with an original image.

FIGS. **3**A and **3**B show examples of the original and defocused images.

FIGS. **4**A and **4**B illustrate a technique of varying the corresponding relationship between Z-values and alpha-values to control the range of depth of field.

FIGS. **5**A and **5**B illustrate a technique of varying the corresponding relationship between Z-values and alpha-values to control the defocusing effect.

FIGS. **6**A, **6**B and **6**C illustrate a technique of sectionalizing areas based on the Z-values to set an alpha-value for each of the sectionalized areas.

FIGS. **7**A, **7**B and **7**C illustrate a technique of updating the alpha-value for a farther pixel in an object by drawing the object.

FIGS. **8**A, **8**B and **8**C illustrate the details of another alpha-value updating technique.

FIGS. **9**A, **9**B, **9**C and **9**D illustrate the details of still another alpha-value updating technique.

FIG. **10** illustrates the texture mapping in the bi-linear filtering method.

FIG. **11** illustrates a technique of generating a defocused image by effectively using the bi-linear filtering method.

FIG. **12** illustrates another technique of generating a defocused image by effectively using the bi-linear filtering method.

FIGS. **13**A and **13**B illustrate a principle of generating a more defocused image through the interpolation in the bi-linear filtering method.

FIGS. **14**A and **14**B illustrate another principle of generating a more defocused image through the interpolation in the bi-linear filtering method.

FIG. **15** is a flowchart illustrating the details of a process in this embodiment.

FIG. **16** is a flowchart illustrating the details of an alpha-plane generating process.

FIG. **17** is a hardware arrangement which can realize this embodiment.

FIGS. **18**A, **18**B and **18**C show various system configurations to which this embodiment can be applied.

BEST MODE FOR CARRYING OUT THE INVENTION

A preferred embodiment of the present invention will now be described with reference to the drawings.

1. Layout

FIG. **1** shows a block diagram of this embodiment. In this figure, this embodiment may comprise at least a processing section **100** (or a processing section **100** with a storage section **170** or a processing section **100** with a storage section **170** and an information storage medium **180**). Each of the other blocks (e.g., control section **160**, display section **190**, sound output section **192**, portable information storage device **194** and communication section **196**) may take any suitable form.

The processing section **100** is designed to perform various processings for control of the entire system, commands to the respective blocks in the system, game processing, image processing, sound processing and so on. The function thereof may be realized through any suitable hardware means such as various processors (CPU, DSP and so on) or ASIC (gate array or the like) or a given program (or game program).

The control section **160** is used to input operational data from the player and the function thereof maybe realized through any suitable hardware means such as a lever, a button, a housing or the like.

The storage section **170** provides a working area for the processing section **100**, communication section **196** and others. The function thereof may be realized by any suitable hardware means such as RAM or the like.

The information storage medium (which may be a computer-usable storage medium) **180** is designed to store information including programs, data and others. The function thereof maybe realized through any suitable hardware means such as optical memory disk (CD or DVD), magneto-optical disk (MO), magnetic disk, hard disk, magnetic tape, memory (ROM) or the like. The processing section **100** performs various processings in the present invention (or this embodiment) based on the information that has been stored in this information storage medium **180**. In other words, the information storage medium **180** stores various pieces of information (or programs and data) for realizing (or executing) the means of the present invention (or this embodiment) which are particularly represented by the blocks included in the processing section **100**.

Part or the whole of the information stored in the information storage medium **150** will be transferred to the storage section **170** when the system is initially powered on. The information stored in the information storage medium **180** may contain at least one of program code set for processing the present invention, image data, sound data, shape data of objects to be displayed, table data, list data, information for instructing the processings in the present invention, information for performing the processings according to these instructions and so on.

The display section **190** is to output an image generated according to this embodiment and the function thereof can be realized by any suitable hardware means such as CRT, LCD or HMD (Head-Mount Display).

The sound output section **192** is to output a sound generated according to this embodiment and the function thereof can be realized by any suitable hardware means such as speaker.

The portable information storage device **194** is to store the player's personal data and save data and may be take any suitable form such as memory card, portable game machine and so on.

The communication section **196** is designed to perform various controls for communication between the game system and any external device (e.g., host device or other image generating system). The function thereof may be realized through any suitable hardware means such as various types of processors or communication ASIS or according to any suitable program.

The program or data for executing (or executing) the means in the present invention (or this embodiment) may be delivered from an information storage medium included in a host device (or server) to the information storage medium **180** through a network and the communication section **196**. The use of such an information storage medium in the hose device (or server) falls within the scope of the invention.

The processing section **100** further comprises a game processing section **110**, an image generating section **130** and a sound generating section **150**.

The game processing section **110** is designed to perform various processes such as coin (or charge) reception, setting of various modes, game proceeding, setting of scene selection, determination of the position and rotation angle (about X-, Y- or Z-axis) of an object (one or more primitive faces), movement of the object (motion processing), determination of the viewpoint (or virtual camera's viewpoint) and view angle (or rotational angle of the virtual camera), arrangement of an object (or mapped object) within the object space, hit checking, computation of the game results (or scores), processing for causing a plurality of players to play in a common game space, various game computations including game-over and other processes, based on operational data from the control section **160** and according to the personal data, saved data and game program from the portable information storage device **194**.

The image generating section **130** is to perform various image processings according to the commands or the like from the game processing section **110**. For example, the image generating section **130** may generate an image viewable from the virtual camera (or viewpoint) within the object space and output it toward the display section **190**. The sound generating section **150** is to perform various sound processings according to the commands and the like from the game processing section **110**. The sound generating section **150** may generate various sounds such as BGMs, sound effects, voices or the like and output them toward the sound output section **192**.

All the functions of the game processing section **110** and image, sound processing sections **130**, **150** may be realized by any suitable hardware means or according to the program. Alternatively, these functions may be realized by both the hardware means and program.

The image generating section **130** comprises a geometry processing (or three-dimensional calculation) section **132**, an alpha-value setting section **134**, a defocused-image generating section **136** and a drawing (or rendering) section **140**.

The geometry processing section **132** is designed to perform various geometry processings (three-dimensional calculations) such as coordinate transformation, clipping, perspective transformation and light source calculation. Object data (such as shape data including object vertex coordinates, vertex texture coordinates, brightness data and the like) obtained after the geometry processing (or perspective transformation) are then saved in a main memory **172** of the storage section **170**.

The alpha-value setting section **134** is designed to set the alpha-value for each pixel (which is information stored in association with each pixel and may be information other than the color information) into a value corresponding to the Z-value (which is a depth value in a broad sense) for each pixel in an original image (e.g., perspectively transformed image). The alpha-value setting section **134** can variably control the range of depth of field and defocusing effect by varying the corresponding relationship between the depth value for each pixel and the alpha-value. Moreover, the alpha-value setting section **134** is to set the alpha-value for each pixel such that as that pixel is farther from the focus of the virtual camera, the alpha-value thereof will increase (or, in a broad sense, the synthesis ratio of the defocused image will increase).

The defocused-image generating section **136** is designed to generating a defocused (or most defocused) image obtained from an alpha-synthesis (e.g., alpha-blending, alpha-addition, alpha-subtraction, translucency processing or the like) with the original image.

More particularly, this embodiment effectively uses the bi-linear filtering method (which is, in a broad sense, a texel interpolation method including the tri-linear filtering method or the like) for texture mapping to generate a defocused image. In other words, the defocused-image generating section **136** is to set the original image as a texture and to shift (or slide or move) the texture coordinates of an object (which is a virtual object having the same shape as that of a defocused area), for example, by a value smaller than one texel when the texture is mapped on the object through the bi-linear filtering method. Thus, the defocused image to be synthesized with the original image can be generated through a simple process in which the texture coordinates are only shifted.

The drawing section **140** is designed to draw an object viewable from the virtual camera within the object space, based on the object data, texture and so on.

The drawing section **140** comprises a texture mapping section **142**, an alpha-synthesis section **144** and a hidden-surface removal section **146**.

The texture mapping section **142** is designed to map a texture stored in a texture storage section **176** on an object (consisted of primitive faces such as polygons, free-form surfaces or the like) through the bi-linear filtering method (texel interpolation method) or a point sampling method.

The alpha-synthesis section **142** is designed to synthesize the original image with a defocused image generated by the defocused-image generating section **136**, based on the alpha-value (or A-value) set for each pixel by the alpha-value setting section **134**. For example, if the alpha-synthesis is the alpha-blending, the synthesis of the original image with the defocused image will be performed as represented by the following formulas:

$$R_Q=(1-\alpha)\times R_1+\alpha\times R_2 \quad (1)$$

$$G_Q=(1-\alpha)\times G_1+\alpha\times G_2 \quad (2)$$

$$B_Q=(1-\alpha)\times B_1+\alpha\times B_2 \quad (3)$$

where R_1, G_1, B_1 are R, G and B color (or brightness) components in the original image which has previously been drawn in a frame buffer **174**; R_2, G_2, B_2 are R, G and B color components in the defocused image generated by the defocused-image generating section **136**; and R_Q, G_Q, B_Q are output images generated through the alpha-blending.

The hidden-surface removal section **144** uses a Z buffer **178** (Z-plane) stored the Z-value (depth value) to erase the hidden surface according to the Z-buffer algorithm. This embodiment uses the function of the hidden-surface removal section **144** to update the alpha-value on drawing the virtual object.

The image generating system of this embodiment may be dedicated for a single-player mode in which only a single player can play the game or may have a multi-player mode in which a plurality of players can play the game.

If a plurality of players play the game, only a single terminal may be used to generate game images and sounds to be provided to all the players. Alternatively, a plurality of terminals interconnected through a network (transmission lien or communication line) may be used in the present invention.

2. Features of this Embodiment 2.1 Alpha(α)-synthesis

As shown by E**1** in FIG. **2**, this embodiment sets alpha-values αA, αB, αC and αD for the respective pixels A, B, C and D in an original image into values corresponding to the respective Z-values ZA, ZB, ZC and ZD in the pixels A, B, C and D to generate an alpha-plane (in which the alpha-value for each pixel is set) as shown by E**2**. More particularly, the alpha-value may increase close to 1.0 as a pixel is farther than the focus (or fixation point) of the virtual camera **10** (or as a pixel has its larger difference between the Z-values of that pixel and focus). Thus, the synthesis ratio of the defocused image increases as the pixel is farther than the focus of the virtual camera **10**.

The Z-value may increase as the pixel is farther or closer to the virtual camera **10**. The synthesis ratio of the defocused image may increase as the alpha-value approaches 1.0 (100%) or 0.0 (0%). In such a case, the aforementioned formulas (1), (2) and (3) will be used replacing α−1 with α.

In this embodiment, as shown by E**3** in FIG. **2**, the alpha-synthesis of the original image with the defocused image (e.g., alpha-blending or the like) is carried out based on the generated alpha-plane (which is, in a broad sense, alpha-value set for each pixel) . FIGS. **3**A and B show original and defocused images obtained through the alpha-synthesis.

When the alpha-synthesis of the original image with the defocused image is carried out based on the alpha-values set corresponding to the Z-values (or depth values) in such a manner, a so-called depth of field can be represented such that an image located farther than the focus of the virtual camera (which is set as a focused point) is generated as a more defocused image. Thus, a more real and natural image can be generated to be focused depending on the distance from the viewpoint as in the real world, unlike the game image of the prior art in which all the objects in the screen were focused. As a result, the virtual reality for players can highly be improved.

In addition, this embodiment does not require any calculation based on the positional relationship between each of the objects and the viewpoint. Therefore, the depth of field can be represented with reduced processing load. It is of course that such a calculation may be carried out in the present invention.

2.2 Alpha-value Setting

FIGS. **4**A, **4**B and FIGS. **5**A, **5**B illustrate the setting of alpha-values depending on the Z-values.

As shown in FIG. **4**A, for example, areas AR**0** to AR**4** and AR**1'** to AR**4'** are sectionalized based on Z-values Z**1** to Z**4** and Z**1'** to Z**4'** (threshold values). alpha-values $\alpha\mathbf{0}$ to $\alpha\mathbf{4}$ and $\alpha\mathbf{1}'$ to $\alpha\mathbf{4}'$ are set to these areas AR**0** to AR**4** and AR**1'** to AR**4'**.

For example, an alpha-value $\alpha\mathbf{1}$ may be set for an pixel in the area AR**1** between Z**1** and Z**2**; another alpha-value $\alpha\mathbf{2}$ may be set for an pixel in the area AR**2** between Z**2** and Z**3**; still another alpha-value $\alpha\mathbf{1}'$ may be set for an pixel in the area AR**1'** between Z**1'** and Z**2'**; and a further alpha-value $\alpha\mathbf{2}'$ may be set for an pixel in the area AR**2'** between Z**2'** and Z**3'**.

The alpha-values set for the respective areas may be set based on the following relational expressions:

$$\alpha\mathbf{0} < \alpha\mathbf{1} < \alpha\mathbf{2} < \alpha\mathbf{3} < \alpha\mathbf{4} \quad (4)$$

$$\alpha\mathbf{0} < \alpha\mathbf{1}' < \alpha\mathbf{2}' < \alpha\mathbf{3}\ ' < \alpha\mathbf{4}' \quad (5)$$

As will be apparent from these relational expressions (4) and (5), the alpha-value will increase as the pixel thereof is farther from the focus (or fixation point) of the virtual camera **10**. If α is replaced by α−1 in the relational expressions (1), (2) and (3), the alpha-value will reversely decrease as the pixel thereof is farther from the focus of the virtual camera **10**. In other words, this embodiment sets the alpha-value such that the synthesis ratio of the defocused image increases as the difference between the focus of the virtual camera **10** and the Z-value increases.

Moreover, this embodiment variably controls the range of depth of field or defocusing effect by varying the corresponding relationship between the Z-value and alpha-value for each pixel.

For example, it is now assumed that a range in which the alpha-value becomes smaller than 1.0 (or the synthesis ratio of the defocused image becomes smaller than 100%) is defined to be a range of depth of field. Thus, the range of depth of field can be increased when the Z-value is coordinated with the alpha-value in such a manner as shown in FIG. **4**A. On the other hand, the range of depth of field can be decreased when the Z-value is coordinated with the alpha-value in such a manner as shown in FIG. **4**B.

The alpha-value specifying the boundary in the range of depth of field is not limited to 1.0, but may be optional.

If the Z-value is coordinated with the alpha-value as shown in FIG. **5**A, the defocusing effect can be decreased while if the Z-value is coordinated with the alpha-value as shown in FIG. **5**B, the defocusing effect can be increased. In other words, the alpha-values in the area AR**2** (or AR**2'**) between Z**2** and Z**3** (or between Z**2'** and Z**3'**) are set to 0.4 (or decreased defocusing effect) in FIG. **5**A while the alpha-values in the area AR**2** (or AR**2'**) are set to 0.7 (or increased defocusing effect) in FIG. **5**B.

As shown in FIG. **6**A, this embodiment performs the sectionalization of areas and the setting of alpha-value to the respective areas both on the farther and nearer sides to the focus. As shown in FIG. **6**B, however, the sectionalization of areas and the setting of alpha-value to the respective areas may be carried out only on the farther side from the focus. Alternatively, as shown in FIG. **6**C, the sectionalization of areas and the setting of alpha-value to the respective areas may be carried out only on the nearer side to the focus.

The setting of alpha-values as shown in FIGS. **6**A, B and C can be realized through a technique which will be described in detail below.

As shown in FIG. **7**A, an object OB**1** (polygon) having its Z-value set to Z**1** is first drawn in a frame buffer (which is, in a broad sense, the drawing area in an original image) . The alpha-value for a pixel located on the farther side (which is, in abroad sense, the first direction including the nearer side) from the object OB**1** is then updated. In other words, the hidden-surface removal process (or Z-butter process) based on the Z-value is effectively used to update the alpha-value for a pixel located farther from the object OB**1**.

As shown in FIG. **7**B, another object OB**2** having its Z-value set to Z**2** is then drawn in the frame buffer to update the alpha-value for a pixel located farther from the object OB**2**. Similarly, as shown in FIG. **7**C, still another object OB**3** having its Z-value set to Z**3** is then drawn in the frame buffer to update the alpha-value for a pixel located farther from the object OB**3**.

By using such a technique, the alpha-values for the pixels in the areas AR**1**, AR**2** and AR**3** can be set to $\alpha\mathbf{1}$, $\alpha\mathbf{2}$ and $\alpha\mathbf{3}$, respectively.

And yet, such a technique provides an advantage that the alpha-values can automatically be updated through the hidden-surface removal function using the Z-buffer only by drawing the objects on the frame buffer in which the original image had been drawn. This enables the desired alpha-value to be set to the corresponding pixel in each area with substantially reduced processing load.

FIGS. **8**A to **9**D illustrate the more details of the alpha-value (or alpha-plane) setting technique.

As shown in FIG. **8**A, the alpha-values in all the areas AR**0** to AR**3** and AR**1'** to AR**3'** are first initialized, for example, to (111) (where the alpha-values being of 3 bits).

As shown in FIG. **8**B, the Z-value is then set to Z**1'** and an object OB**1'** (near) having its alpha-value set, for example, to (000) is drawn in the frame buffer. Thus, the first bit of the alpha-value for a pixel located farther from of or nearer to the object OB**1'** (which is, in a broad sense, the first direction) is updated, for example, to 0 (which is, in a broad sense, first level). In such a case, however, the bits other than the first bit (or bit to be updated) are masked.

As shown in FIG. **8**C, the Z-value is then set to Z**1** and an object OB**1** having its alpha-value set, for example, to (111) is drawn in the frame buffer. Thus, the first bit of the alpha-value for a pixel located farther from the object OB**1** (far) is updated, for example, to 1 (which is, in a broad sense, second level). In such a case, however, the bits other than the first bit are also masked.

In such a manner, the alpha-value in the area AR**0** is set to (110) while the alpha-values in the other areas are set to (111). Namely, the alpha-value set in the area AR**0** can be different from the alpha-values in the other areas.

As shown in FIG. **9**A, an object OB**2'** having its alpha-value=(000) is then drawn at Z=Z**2'** to update the second bit of the alpha-value for a pixel located farther from the object OB**2'** to 0 (with the bits other than the second bit being masked).

As shown in FIG. **9**B, an object OB**2** having its alpha-value=(111) is then drawn at Z=Z**2** to update the second bit of the alpha-value for a pixel located farther from the object OB**2** to 1 (with the bits other than the second bit being masked).

In such a manner, the alpha-value in the area AR**0** is set to (100); the alpha-values in the areas AR**1'** and AR**1** are set to (101); and the alpha-values in the other areas are set to (111).

As shown in FIG. **9**C, an object OB**3'** having its alpha-value=(000) is then drawn at Z=Z**3'** to update the third bit of the alpha-value for a pixel located farther from the object OB**3'** to 0 (with the bits other than the third bit being masked).

As shown in FIG. **9**D, an object OB**3** having its alpha-value=(111) is then drawn at Z=Z**3** to update the third bit of the alpha-value for a pixel located farther from the object OB**3** to 1 (with the bits other than the third bit being masked).

In such a manner, the alpha-value in the area AR**0** is set to (000); the alpha-values in the areas AR**1'** and AR**1** are set to (001); the alpha-values in the areas AR**2'** and AR**2** are set to (001); and the alpha-values in the areas AR**3'** and AR**3** are set to (111).

Namely, a pixel having its increased difference of Z-value relative to the focus of the virtual camera **10** will be set to be increased in alpha-value, thus resulting in increase of the synthesis ratio of the defocused image. Therefore, the alpha-value optimum to the representation of the depth of field can be realized through a simple and high-speed process in which the objects are only drawn masking the particular bits.

There has described the updating of the alpha-value for a pixel located farther from an object merely by drawing that object. However, if the image generating system has a function of updating the alpha-value for a pixel located nearer to an object by drawing that object or a function of inverting the Z-value, the alpha-value for a pixel located nearer to the object may be updated by drawing the object.

2.3 Generation of Defocused Image

This embodiment effectively uses the bi-linear filtering method (or texel interpolation method) for texture mapping to generate the defocused image (FIG. **3**B) to be synthesized with the original image (FIG. **3**A).

In the texture mapping, the position of a pixel may be offset from the position of a texel.

In such a case, the point sampling method is such that a color CP (which is, in a broad sense, image information) at a pixel (or sampling point) P becomes a color CA at a texel TA nearest to the point P, as shown in FIG. **10**.

On the other hand, the bi-linear filtering method is such that the color CP at the point P becomes a color obtained by interpolating colors CA, CB, CC and CD at texels TA, TB, TC and TD around the point P.

More particularly, a coordinate ratio β: 1−β (0≦β≦1) in the X-axis direction and a coordinate ratio γ: 1−γ (0≦γ≦1) in the Y-axis direction are determined based on the coordinates of TA to TD and the coordinates of P.

In this case, the color CP (or output color through the bi-linear filtering method) at P can be represented by the following formula:

$$CP=(1-\beta)\times(1-\gamma)\times CA+\beta\times(1-\gamma)\times CB+ \qquad (6)$$

$$(1-\beta)\times\gamma\times CC+\beta\times\gamma\times CD$$

For generating the defocused image, this embodiment aims to the fact that the bi-linear filtering method automatically interpolates the color in such a manner.

More particularly, as shown by F**1** in FIG. **11**, an original image drawn, for example, in the frame buffer is set as a texture. When this texture (or original image) is to be mapped on an object through the bi-linear filtering method, the texture coordinates for each vertex in the object are shifted (or slid or moved) in the rightward and downward direction, for example, by (0.5, 0.5). Thus, a defocused image in which the pixel colors in the original image spread the surrounding area can be generated automatically through the interpolation in the bi-linear filtering method.

Where it is desired to defocus the entire scene, the shape of an object on which the texture (or original image) is mapped is set to be identical with that of the scene (defocused area) In other words, if the vertex coordinates of the scene are (X, Y)=(0, 0), (640, 0), (640, 480) and (0, 480), the vertex coordinates in the object are also (X, Y)=(0, 0), (640, 0), (640, 480) and (0, 480).

If in such a case, texture coordinates (U, V) provided to the vertexes VX**1**, VX**2**, VX**3** and VX**4** of an object are set to be respectively (0, 0), (640, 0), (640, 480) and (0, 480), the positions of the scene pixels coincide with the texel positions of a texture. Therefore, the image will not be defocused.

On the contrary, if the texture coordinates (U, V) provided to the vertexes VX**1**, VX**2**, VX**3** and VX**4** of the object are set to be respectively (0.5, 0.5), (640.5, 0.5), (640.5, 480.5) and (0.5, 480.5), the positions of the scene pixels will offset from the texel positions of a texture. Therefore, the image will be viewed defocused by color interpolation through the interpolation of the bi-linear filtering method.

If it is desired to defocus only part of the scene, the shape of the object may be identical with that of the defocused area.

As shown by G**1** in FIG. **12**, this embodiment sets the original image as a texture and then shifts it, for example, in the rightward and downward direction (or first shift direction) by 0.5 texel. Thus, the texture mapping is performed through the bi-linear filtering method to generate a first defocused image. As shown by G**2** in FIG. **12**, the first defocused image is then set as a texture and shifts it , for example, in the leftward and upward direction (or second shift direction) by 0.5 texel. Thus, the texture mapping is performed through the bi-linear filtering method to generate a second defocused image. Alternatively, a plurality of such processes (shifts in the rightward and downward direction and in the leftward and upward direction) maybe repeated. Thus, a natural defocused image can be generated.

The principle of generating a defocused image through the interpolation of the bi-linear filtering method will be described below.

It is now assumed that the texture coordinates have been shifted in the rightward and downward direction by 0.5 texels and the texture mapping has been carried out through the bi-linear filtering method, as shown in FIG. **13**A. In this case, β=γ=½ in the above formula (6). Thus, if it is assumed that texels T**44**, T**45**, T**54** and T**55** have their colors C**44**, C**45**, C**54** and C**55**, the color CP**44** of a pixel P**44** is represented by:

$$CP44=(C44+C45+C54+C55\ )/4 \qquad (7).$$

As will be seen from the foregoing, the transformation shown in FIG. **13**A will cause the color C**44** of the texel T**44** (which corresponds to the original color in the pixel P**44** of the original not-transformed image) to spread to the surrounding pixels P**33**, P**34**, P**43** and P**44** each by ¼.

It is thereafter assumed that the image obtained in FIG. **13**A is used as a texture and that the texture mapping is carried out through the bi-linear filtering method after the texture coordinates thereof have been shifted in the leftward and upward direction by 0.5 texels, as shown in FIG. **13**B. In this case, the pixels P**33**, P**34**, P**43** and P**44** of FIG. **13**A will correspond to the texels T**33**, T**34**, T**43** and T**44** of FIG. **13**B, respectively. Thus, the color C**44**, which has spread to the pixels P**33**, P**34**, P**43** and P**44** (T**33**, T**34**, T**43** and T**44**) each by $\frac{1}{4}$ in FIG. **3**A, will further spread to the four surrounding pixels each by $\frac{1}{4}$. As a result, the color C**44** of the original texel T**44** will spread to the surrounding pixels by $\frac{1}{16}=\frac{1}{4}\times\frac{1}{4}$.

Therefore, the transformations of FIGS. **13**A and B will cause the color C**44** (which corresponds to the original color of the pixel P**44** in the original image drawn in the frame buffer) to spread to the pixels P**33**, P**34** and P**35** by $\frac{1}{16}$, $\frac{2}{16}$ and $\frac{1}{16}$, respectively. Moreover, the color C**44** will spread to the pixels P**43**, P**44** and P**45** by $\frac{2}{16}$, $\frac{4}{16}$ and $\frac{2}{16}$, respectively. The color C**44** will spread to the pixels P**53**, P**54** and P**55** by $\frac{1}{16}$, $\frac{2}{16}$ and $\frac{1}{16}$, respectively.

As a result, the transformations of FIGS. **13**A and B will apply such a plane filter as shown in FIG. **14**A to the original image. This plane filter can generate an ideal defocused image for the original image by uniformly spreading the colors of the respective pixels in the original image to the surrounding pixels.

If the transformations of FIGS. **13**A and B are twice repeated as a set, such a plane filter as shown in FIG. **14**B will be applied to the original image. Such a plane filter can generate a more ideal defocused image than that of FIG. **14**A.

3. Process of this Embodiment

The detailed process of this embodiment will be described in connection with the flowcharts of FIGS. **15** and **16**.

The original image (or perspectively transformed image) is first drawn in the frame buffer (step S**1**). The technique as described in connection with FIGS. **8**A to **9**D is then used to prepare an alpha-plane (or alpha-channel) (step S**2**). Then j is initialized to 0 (step S**3**).

Subsequently, as shown by G**1** in FIG. **12**, the original image in the frame buffer is then set as a texture which is in turn mapped on a another buffer (step S**4**). At this time, the mapping is carried out through the bi-linear filtering method after the texture coordinates have been shifted by (0.5, 0.5).

Subsequently, as shown by G**2** in FIG. **12**, the image in the other buffer is set as a texture which is in turn mapped onto the frame buffer (step S**5**). At this time, the mapping is carried out through the bi-linear filtering method after the texture coordinates have been shifted by (−0.5, −0.5). At the same time, as shown by E**3** in FIG. **2**, the alpha-plane generated at the step **S2** is used to perform the alpha-blending between the original image (FIG. **3**A) and the defocused image (FIG. **3**B).

Then j is incremented by one (step S**6**). It is judged whether or not j exceeds M (the number of repeated defocusing transformations) (step S**7**). If not so, the procedure returns to the step S**4**. If the j exceeds the M, the procedure is terminated.

FIG. **16** is a detailed flowchart of generating the alpha-plane shown in FIG. **15**.

As described in connection with FIG. **8**A, all the alpha-values in the alpha-plane are initialized with 2^m-2^{n-1} (step S**10**). Then i is initialized to n (step S**11**).

Symbols m and n used herein represent the maximum and minimum bits in the prepared alpha-plane, respectively. For example, if the alpha-value is 8 bits and m and n are respectively equal to 6 and 4, the alpha-value of the alpha-plane is initialized to (00111000) at the step S**10**. In other words, the initialization at the step S**10** will initialize the alpha-value so that all the m–n bits are made one (1) with the other bits being made zero (0).

All the R, G, B and alpha-values of the original image in the frame buffer are then masked except the i-th bit in the alpha-value (step S**12**). As described in connection with FIG. **8**B, an object (or polygon) having Z=Zi' (near) and α=(00000000) is then drawn in the frame buffer to update the alpha-value of a pixel located farther from that object (step S**13**). As described in connection with FIG. **8**C, another object having Z=Zi (far) and α=(11111111) is then drawn in the frame buffer to update the alpha-value of a pixel located farther from that object (step S**14**).

Then i is incremented by one (step S**15**). It is then judged whether or not i exceeds K (step S**16**). If not so, the procedure returns to the step S**12**. If i exceeds K, the process of preparing the alpha-plane is terminated.

4. Hardware Arrangement

A hardware arrangement which can realize this embodiment is shown in FIG. **17**.

A main processor **900** operates to execute various processings such as game processing, image processing, sound processing and other processings according to a program stored in a CD (information storage medium) **982**, a program transferred through a communication interface **990** or a program stored in a ROM (information storage medium) **950**.

A coprocessor **902** is to assist the processing of the main processor **900** and has a product-sum operator and analog divider which can perform high-speed parallel calculation to execute a matrix (or vector) calculation at high speed. If a physical simulation for causing an object to move or act (motion) requires the matrix calculation or the like, the program running on the main processor **900** instructs (or asks) that processing to the coprocessor **902**.

A geometry processor **904** is to perform a geometry processing such as coordinate transformation, perspective transformation, light source calculation, curve formation or the like and has a product-sum operator and analog divider which can perform high-speed parallel calculation to execute a matrix (or vector) calculation at high speed. For example, for the coordinate transformation, perspective transformation or light source calculation, the program running on the main processor **900** instructs that processing to the geometry processor **904**.

A data expanding processor **906** is to perform a decoding process for expanding image and sound compressed data or a process for accelerating the decoding process in the main processor **900**. In the opening, intermission, ending or game scene, thus, an MPEG compressed animation may be displayed. The image and sound data to be decoded may be stored in the storage devices including ROM **950** and CD **982** or may externally be transferred through the communication interface **990**.

A drawing processor **910** is to draw or render an object constructed by primitive faces such as polygons or curved faces at high speed. On drawing the object, the main processor **900** uses a DMA controller **970** to deliver the object data to the drawing processor **910** and also to transfer a texture to a texture storage section **924**, if necessary. Thus, the drawing processor **910** draws the object in a frame buffer **922** at high speed while performing a hidden-surface removal by the use of a Z-buffer or the like, based on the object data and texture. The drawing processor **910** can also perform alpha-blending (or translucency processing), depth cueing, mip-mapping, fogging, bi-linear filtering, tri-linear filtering, anti-aliasing, shading and soon. As the image for one frame is written into the frame buffer **922**, that image is displayed on a display **912**.

A sound processor **930** includes any multi-channel ADPCM sound source or the like to generate high-quality game sounds such as BGMs, sound effects and voices. The generated game sounds are outputted from a speaker **932**.

The operational data from a game controller **942**, saved data from a memory card **944** and personal data may externally be transferred through a serial interface **940**.

ROM **950** has stored a systemprogram and soon. For an arcade game system, the ROM **950** functions as an information storage medium in which various programs have been stored. The ROM **950** may be replaced by any suitable hard disk.

RAM **960** is used as a working area for various processors.

The DMA controller **970** controls the DMA transfer among processors and memories (such as RAM, VRAM and ROM).

The CD drive **980** drives a CD (information storage medium) **982** in which the programs, image data or sound data have been stored and enables these programs and data to be accessed.

The communication interface **990** is to perform data transfer between the image generating system and any external instrument through a network. In such a case, the network connectable with the communication interface **990** may take any of communication lines (analog phone line or ISDN) or high-speed serial interface bus. The use of the communication line enables the data transfer to be performed through the INTERNET. If the high-speed serial interface bus is used, the data transfer may be carried out between the image generating system and any other image generating system or any other game system.

All the means of the present invention may be executed only through hardware or only through a program which has been stored in an information storage medium or which is distributed through the communication interface. Alternatively, they may be executed both through the hardware and program.

If all the means of the present invention are executed both through the hardware and program, the information storage medium will have stored a program for realizing (or executing) the means of the present invention through the hardware. More particularly, the aforementioned program instructs the respective processors **902**, **904**, **906**, **910** and **930** which are hardware and also delivers the data to them, if necessary. Each of the processors **902**, **904**, **906**, **910** and **930** will execute the corresponding one of the means of the present invention based on the instruction and delivered data.

FIG. **18**A shows an arcade game system to which this embodiment is applied. Players enjoy a game by controlling levers **1102** and buttons **1104** while viewing a game scene displayed on a display **1100**. A system board (circuit board) **1106** included in the game system includes various processor and memories which are mounted thereon. Information (program or data) for realizing all the means of the present invention has been stored in a memory **1108** on the system board **1106**, which is an information storage medium. Such information will be referred to “stored information” later.

FIG. **18**B shows a home game apparatus to which this embodiment is applied. A player enjoys a game by manipulating game controllers **1202** and **1204** while viewing a game picture displayed on a display **1200**. In such a case, the aforementioned stored information pieces have been stored in DVD **1206** and memory cards **1208**, **1209** which are detachable information storage media in the game system body.

FIG. **18**C shows an example wherein this embodiment is applied to a game system which includes a host device **1300** and terminals **1304-1** to **1304**-n connected to the host device **1300** through a network (which is a small-scale network such as LAN or a global network such as INTERNET) **1302**. In such a case, the above stored information pieces have been stored in an information storage medium **1306** such as magnetic disk device, magnetic tape device, semiconductor memory or the like which can be controlled by the host device **1300**, for example. If each of the terminals **1304-1** to **1304**-n are designed to generate game images and game sounds in a stand-alone manner, the host device **1300** delivers the game program and other data for generating game images and game sounds to the terminals **1304-1** to **1304**-n. On the other hand, if the game images and sounds cannot be generated by the terminals in the stand-alone manner, the host device **1300** will generate the game images and sounds which are in turn transmitted to the terminals **1304-1** to **1304**-n.

In the arrangement of FIG. **18**C, the means of the present invention may be decentralized into the host device (or server) and terminals. The above information pieces for realizing the respective means of the present invention may be distributed and stored into the information storage media of the host device (or server) and terminals.

Each of the terminals connected to the network may be either of home or arcade type. When the arcade game systems are connected to the network, it is desirable that each of the arcade game systems includes a portable information storage device (memory card or portable game machine) which can not only transmit the information between the arcade game systems but also transmit the information between the arcade game systems and the home game systems.

The present invention is not limited to the things described in connection with the above forms, but may be carried out in any of various other forms.

For example, the invention relating to one of the dependent claims may not contain part of the structural requirements in any claim to which the one dependent claim belongs. The primary part of the invention defined by one of the independent claim may be belonged to any other independent claim.

It is desirable that the setting of alpha-value is carried out through such a technique as described in connection with FIGS. **6**A to **9**D. However, the present invention is not limited to such a technique. For example, the alpha-value may continuously be varied depending on the change of the depth value (Z-value), rather than the stepwise manner.

Although it is desirable that the defocused image to be synthesized with the original image is generated through such a technique as described in connection with FIGS. **11** and **12**, the present invention is not limited to such a technique. For example, the defocused image may be generated by synthesizing the original image with an image obtained by offsetting the original image or by synthesizing an original image in one frame with another original image in the previous frame.

In the invention in which the alpha-value is set as in FIGS. **6**A to **9**D, the set alpha-value may be utilized to various other image drawings, rather than the synthesis between the original image and the defocused image. For example, the set alpha-value may be used to make an object located farther than the viewpoint translucent so that it will merge into the background.

The invention in which the defocused image is generated through the texel interpolation method is not limited to such a technique as described in connection with FIGS. **11** to **14**B. For example, rather than defocusing of the entire scene, a defocused area smaller than the scene may be set to defocus the original image in that area.

Although this embodiment has been described as to the object located farther than the viewpoint being increased in depth value, the present invention is not limited to this. For example, the present invention may similarly be applied to the object located farther than the viewpoint being decreased in depth value.

The present invention may be applied to any of various games such as fighting games, shooting games, robot combat games, sports games, competitive games, roll-playing games, music playing games, dancing games and so on.

Furthermore, the present invention can be applied to various image generating systems such as arcade game systems, home game systems, large-scaled multi-player attraction systems, simulators, multimedia terminals, game image generating system boards and so on.

What is claimed is:

1. An image generating system for generating an image, comprising:

a memory which stores a program and data for image generating; and

at least one processor which is coupled with the memory and performs processing for image generating,

the processor including:

an alpha-value setting section which sets an alpha-value for each pixel to a value corresponding to a depth value of the each pixel in an original image, wherein the value is not associated with color information; and

a synthesizing section which synthesizes the original image with a defocused image corresponding to the original image based on the alpha-value set for each pixel,

wherein the alpha-value setting section sets the alpha-value for the each pixel so that a synthesis ratio of the defocused image becomes higher for a pixel having a larger difference between a focal depth value of a virtual camera and the depth value of the each pixel.

2. The image generating system according to claim **1**,

wherein a range of depth of field or magnitude of defocusing effect is variably controlled by varying a corresponding relationship between the depth value of the each pixel and the alpha-value.

3. The image generating system according to claim **1**, wherein

the alpha-value setting section sets an alpha-value for a pixel having a depth value located in an area AR**1** between Z**1** and Z**2** as α**1**, the alpha-value for a pixel having a depth value located in an area AR**2** between Z**2** and Z**3** as α**2**, . . . , and subsequently the alpha-value for a pixel having a depth value located in an area ARi between Zi and Zi+1 as αi; and

wherein the image generating system further comprises a drawing section which draws an image based on the alpha-value set by the alpha-value setting section.

4. The image generating system according to claim **3**,

wherein the alpha-value setting section updates:

the alpha-value of an pixel located in a first direction from an object OB**1** having the depth value set as Z**1** by drawing the object OB**1** in a drawing area of an original image;

the alpha-value of an pixel located in the first direction from an object OB**2** having the depth value set as Z**2** by drawing the object OB**2** in the drawing area of the original image; . . . and

subsequently the alpha-value of an pixel located in the first direction from an object OBi having the depth value set as Zi by drawing the object OBi in the drawing area of the original image.

5. The image generating system according to claim **4**,

wherein the alpha-value setting section updates only a bit to be updated by masking a bit not to be updated when an object is drawn in the drawing area of the original image to update the alpha-value.

6. The image generating system according to claim **3**,

wherein the alpha-value setting section updates:

an n-th bit in the alpha-value of a pixel located in a first direction from an object OB**1**' having the depth value set as Z**1**' into a first level by drawing the object OB**1**' in a drawing area of an original image, and the n-th bit in the alpha-value of a pixel located in the first direction from an object OB**1** having the depth value set as Z**1** and located in the first direction from the object OB**1**' into a second level by drawing the object OB**1** in the drawing area of the original image;

an (n+1)-th bit in the alpha-value of a pixel located in the first direction from an object OB**2**' having the depth value set as Z**2**' into the first level by drawing the object OB**2**' in the drawing area of the original image, and the (n+1)-th bit in the alpha-value of a pixel located in the first direction from an object OB**2** having the depth value set as Z**2** and located in the first direction from the object OB**2**' into the second level by drawing the object OB**2** in the drawing area of the original image; . . . and

an (n+i−1)-th bit in the alpha-value of a pixel located in the first direction from an object OBi' having the depth value set as Zi' into the first level by drawing the object OBi' in the drawing area of the original image, and the (n+i−1)-th bit in the alpha-value of a pixel located in the first direction from an object OBi having the depth value set as Zi and located in the first direction from the object OBi' into the second level by drawing the object OBi in the drawing area of the original image.

7. A computer-usable program embodied on an information storage medium or in a carrier wave, the program comprising a processing routine to realize:

an alpha-value setting section which sets an alpha-value for each pixel to a value corresponding to a depth value of the each pixel in an original image, wherein the value is not associated with color information; and

a synthesizing section which synthesizes the original image with a defocused image corresponding to the original image based on the alpha-value set for each pixel,

wherein the alpha-value setting section sets the alpha-value for the each pixel so that a synthesis ratio of the defocused image becomes higher for a pixel having a larger difference between a focal depth value of a virtual camera and the depth value of the each pixel.

8. The program according to claim **7**,

wherein a range of depth of field or magnitude of defocusing effect is variably controlled by varying a corresponding relationship between the depth value of the each pixel and the alpha-value.

9. The program according to claim **7**, wherein

the alpha-value setting section sets an alpha-value for a pixel having a depth value located in an area AR**1** between Z**1** and Z**2** as α**1**, the alpha-value for a pixel having a depth value located in an area AR**2** between Z**2** and Z**3** as α**2**, . . . , and subsequently the alpha-value for a pixel having a depth value located in an area ARi between Zi and Zi+1 as αi; and

wherein the program further comprises a drawing section which draws an image based on the alpha-value set by the alpha-value setting section.

10. The program according to claim **9**,

wherein the alpha-value setting section updates:

the alpha-value of an pixel located in a first direction from an object OB**1** having the depth value set as Z**1** by drawing the object OB**1** in a drawing area of an original image;

the alpha-value of an pixel located in the first direction from an object OB**2** having the depth value set as Z**2** by drawing the object OB**2** in the drawing area of the original image; . . . and

subsequently the alpha-value of an pixel located in the first direction from an object OBi having the depth value set as Zi by drawing the object OBi in the drawing area of the original image.

11. The program according to claim **10**,

wherein the alpha-value setting section updates only a bit to be updated by masking a bit not to be updated when an object is drawn in the drawing area of the original image to update the alpha-value.

12. The program according to claim **9**,

wherein the alpha-value setting section updates:

an n-th bit in the alpha-value of a pixel located in a first direction from an object OB**1**' having the depth value set as Z**1**' into a first level by drawing the object OB**1**' in a drawing area of an original image, and the n-th bit in the alpha-value of a pixel located in the first direction from an object OB**1** having the depth value set as Z**1** and located in the first direction from the object OB**1**' into a second level by drawing the object OB**1** in the drawing area of the original image;

an (n+1)-th bit in the alpha-value of a pixel located in the first direction from an object OB**2**' having the depth value set as Z**2**' into the first level by drawing the object OB**2**' in the drawing area of the original image, and the (n+1)-th bit in the alpha-value of a pixel located in the first direction from an object OB**2** having the depth value set as Z**2** and located in the first direction from the object OB**2**' into the second level by drawing the object OB**2** in the drawing area of the original image; . . . and

an (n+i−1)-th bit in the alpha-value of a pixel located in the first direction from an object OBi' having the depth value set as Zi' into the first level by drawing the object OBi' in the drawing area of the original image, and the (n+i−1)-th bit in the alpha-value of a pixel located in the first direction from an object OBi having the depth value set as Zi and located in the first direction from the object OBi' into the second level by drawing the object OBi in the drawing area of the original image.

13. An image generating method for generating an image, comprising:

setting an alpha-value for each pixel to a value corresponding to a depth value of the each pixel in an original image, wherein the value is not associated with color information;

synthesizing the original image with a defocused image corresponding to the original image based on the alpha-value set for each pixel; and

setting the alpha-value for the each pixel so that a synthesis ratio of the defocused image becomes higher for a pixel having a larger difference between a focal depth value of a virtual camera and the depth value of the each pixel.

14. The image generating method according to claim **13**, further comprising:

setting the alpha-value for a pixel having a depth value located in an area AR**1** between Z**1** and Z**2** as α**1**, the alpha-value for a pixel having a depth value located in an area AR**2** between Z**2** and Z**3** as α**2** . . . , and subsequently the alpha-value for a pixel having a depth value located in an area Ari between Zi and Zi+1 as αi; and

drawing an image based on the alpha-value set by the alpha-value setting.

15. The image generating method according to claim **14**, further comprising:

updating the alpha-value of a pixel located in a first direction from an object OB**1** having the depth value set as Z**1** by drawing the object OB**1** in a drawing area of an original image;

updating the alpha-value of a pixel located in the first direction from an object OB**2** having the depth value set as Z**2** by drawing the object OB**2** in the drawing area of the original image; . . . , and

subsequently updating the alpha-value of a pixel located in the first direction from an object OBi having the depth value set as Zi by drawing the object OBi in the drawing area of the original image.

16. The image generating method according to claim **14**, further comprising:

updating an n-th bit in the alpha-value of a pixel located in a first direction from an object OB**1**' having the depth value set as Z**1**' into a first level by drawing the object OB**1**' in a drawing area of an original image, and the n-th bit in the alpha-value of a pixel located in the first direction from an object OB**1** having the depth value set as Z**1** and located in the first direction from the object OB**1**' into a second level by drawing the object OB**1** in the drawing area of the original image;

updating an (n+1)-th bit in the alpha-value of a pixel located in the first direction from an object OB**2**' having the depth value set as Z**2**' into the first level by drawing the object OB**2**' in the drawing area of the original image, and the (n+1)-th bit in the alpha-value of a pixel located in the first direction from an object OB**2** having the depth value set as Z**2** and located in the first direction from the object OB**2**' into the second level by drawing the object OB**2** in the drawing area of the original image; . . . , and

updating an (n+i−1)-th bit in the alpha-value of a pixel located in the first direction from an object OBi' having the depth value set as Zi' into the first level by drawing the object OBi' in the drawing area of the original image, and the (n+i−1)-th bit in the alpha-value of a pixel located in the first direction from an object OBi having the depth value set as Zi and located in the first direction from the object OBi' into the second level by drawing the object OBi in the drawing area of the original image.

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